TRAINING MANUAL FOR MOSQUITO AND BITING FLY CONTROL IN COASTAL AREAS

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UNIVERSITY OF NORTH CAROLINA SEA GRANT PROGRAM
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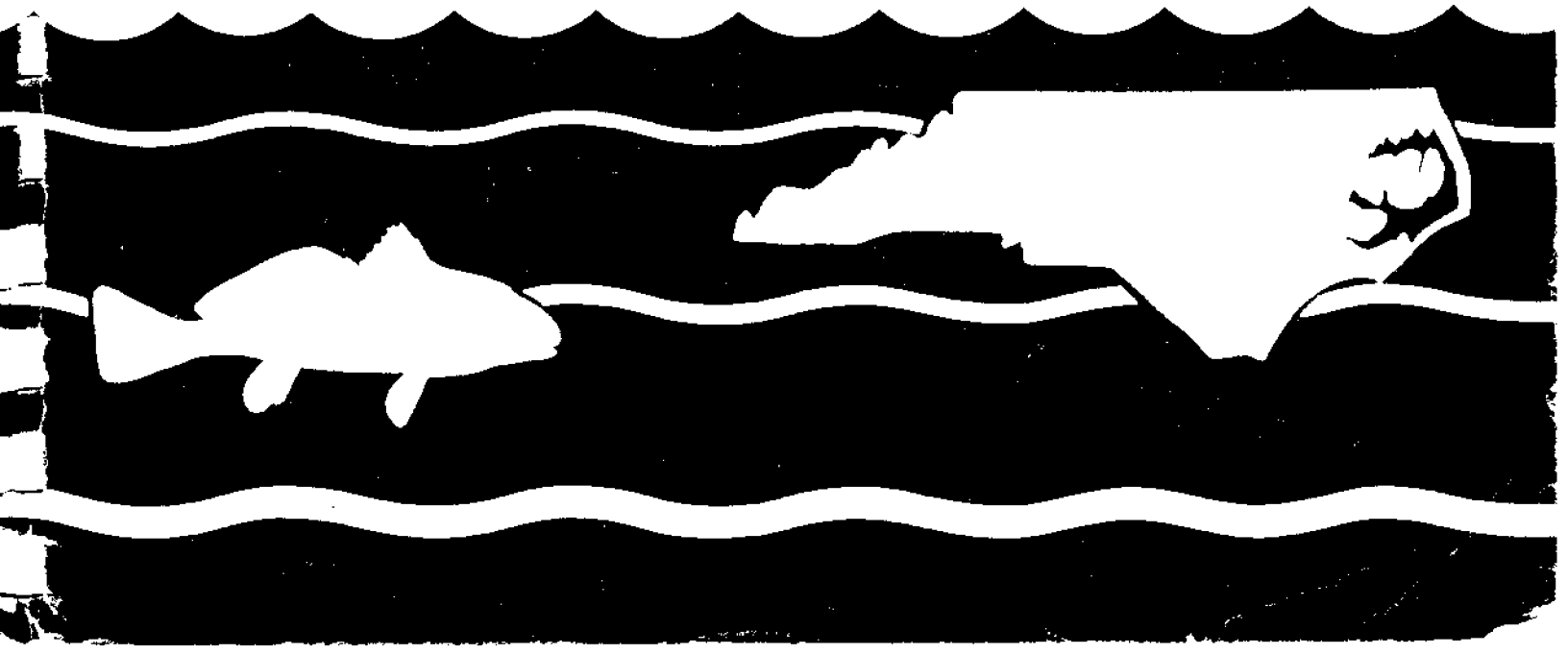

TRAINING MANUAL

FOR

MOSQUITO AND BITING FLY CONTROL

IN COASTAL AREAS

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PREFACE

This manual was developed for use in a two-day "Training Course in Mosquito and Biting Fly Control in Coastal Areas" held at Morehead City, North Carolina, May 8-9, 1974. This was a cooperative effort by the Department of Entomology of North Carolina State University and the Solid Waste and Vector Control Branch, Division of Health Services, North Carolina Department of Human Resources.

This training course and manual have been developed in an attempt to serve the needs of workers (county, municipal and private sector) engaged in community insect pest control, extension agents, fisheries and wildlife biologists, and other interested persons. The emphasis and examples are based on the insect pest situation in the coastal areas of North Carolina. However, much of the material is applicable also to most of the Atlantic coastal areas of the United States.

Both the training sessions and the manual are the initial steps of what is considered to be a continuing need for training in mosquito and biting fly control. From this pilot effort, needed improvements in content and presentation will become apparent. Therefore, it is planned to revise this manual in the future. Suggestions and contributions of material will be greatly appreciated.

RCA

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ACKNOWLEDGMENTS

Diagrams of mosquitoes (pages 37, 38, 39) are courtesy of U. S. Public Health Service, Communicable Disease Center, Atlanta.

Adult mosquito drawings (pages 41-51) are reporduced from "Mosquitoes of North America" by S. J. Carpenter and W. J. LeCasse by permission of the Unitersity of California Press.

Other drawings are originals or adaptations and the preparation of these was possible through the efforts of Nai Chia Kua, Margaret Peoples, and Shuling Tung.

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CONTENTS

1. INTRODUCTION

Control of the mosquitoes and biting flies affecting man and animals in coastal and estuarine areas is a difficult task but is frequently necessary to prevent disease transmission and to provide relief from attack for the citizens and segments of the economy, especially the tourist and recreation industries.

The extreme ecological importance of these areas make it essential that the populations of these insect pests be managed by methods that are compatible with the estuarine ecosystems. Many of the biting flies and mosquitoes breed in the marshes which support an abundance of marine life and are a source of nutrients. Recently, action has been taken to require acceptable environmental impact statements for any ditching or impounding of marshes for mosquito control. The policy of the State of North Carolina is to promote ecological management of the coastal marshes. Ecologically sound insect control in this situation requires the judicious meshing of different methods (chemical, cultural, biological) into a program of pest management. The emphasis must be on the long-term benefits of the marshes rather on the short-term benefits of insect control.

The term "pest management" denotes an approach to the reduction of a pest problem in which decision-making is based on consideration of what is ecologically and economically in the long-term best interest of mankind. Inherent in the concept is an orientation to the entire pest population in a large area. The objective is to lower the mean level of abundance of that population by methods or a combination of method which cause the least disruption of the ecosystems. It is based

on the realization that natural pest populations cannot be eliminated; rather they must be managed so that they occur at tolerable levels.

In the coastal and estuarine ecosystems, management of the biting fly and mosquito populations must take into account the long-term importance of these systems to mankind, not merely the short-term demands of the public or of a segment of the economy. A management program will require measured and selective use of chemical and cultural practices tailored to local conditions and applied in a manner to supplement the natural control agents. The object will be to suppress the pest population below the level of economic importance to man with minimal interference with the estuarine ecosystem.

The coastal region offers an excellent opportunity for the development of pest management programs for biting flies and mosquitoes. The need is great. The vast expanses of estuaries provide breeding areas for large populations of biting insects which are an important limiting factor in the utilization of coastal areas. The demand for the development of coastal recreation facilities is increasing rapidly with the nation's population growth, rising economic level, increase in leisure time, and greater urbanization resulting in an increasing necessity for planned use of accessible, uncongested areas. The coast is on the verge of inundation from the highly concentrated population centers. These visitors seek a reasonably natural setting, but will not tolerate the risk of insect-borne diseases and the severe aggravation of painful insect bites. Therefore, more and more effort will be devoted to the insect control in the coastal areas by local and state agencies and by individual land-owners.

To conduct management programs, more well-trained personnel will be needed. Ecologically sound practices require persons with a broad knowledge and understanding of the pest problem and the ability to analyze the local situation. New legislation (both State and Federal) is requiring that users of pesticides be examined and licensed. This includes personnel using pesticides in mosquito and biting fly control. These requirements are likely to become more stringent in the future In addition to a basic knowledge of pesticides, a demonstrable knowledge of the insect pests and their environment will likely be included.

The important biting insects along the entire coast of the eastern United States are several species of mosquitoes (Family Culicidae), gnats or Culicoides sand flies (Family Ceratopogonidae) and tabanid biting flies (greenheads and deerflies, Family Tabanidae). Different species develop in various portions of the marsh and upland. Before blaming the marshes for the pest problem, the amount of insect breeding in upland areas should be determined. Some mosquitoes breed in tree holes, artificial containers, tires, potholes, etc. However, certain major pest species are often being produced in the marshes. In general (see diagram) the salt marsh Aedes mosquitoes breed in the higher portions of the marshes which are only intermittently flooded (several times a month at irregular intervals). This high marsh area is characterized overall by Juncus (needle rush) vegetation. Often the mosquito breeding is in depressions and specific locations in this high marsh where patches of Distichlis vegetation are found among the Juncus.

In the lower marsh (the areas which are flooded twice a day by each high tide), the mosquitoes do not breed. This regularly flooded, low marsh is characterized by Spartina (smooth cordgrass) vegetation.

However, patches of other vegetation occur due to elevation irregularities. The tabanid biting flies and the Culicoides gnats or sand flies breed in this low marsh. In addition, one of the species of gnats (Culicoides melleus) breeds only in the very sandy margins of these marshes (as well as along the margins of creeks and sounds).

This overview of the insect pest breeding habitats should be kept in mind in analyzing a local situation and in designing an area-wide post management program.

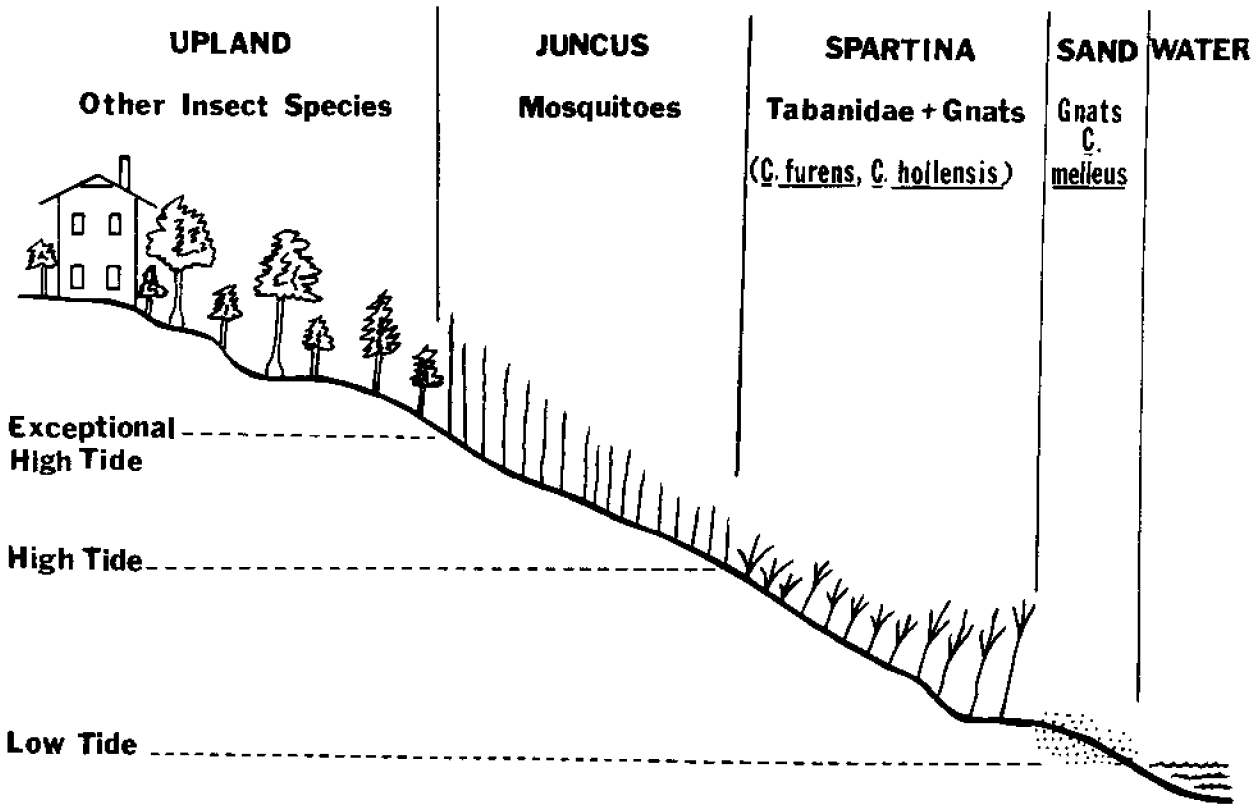


Diagram of salt marsh habitat showing breeding sites of mosquitoes (Culicoidae), deerflies and greenhead flies (Tabanidae) and biting gnats (Culicoides, Ceratopogonidae) in relation to dominant marsh vegetation and tide levels. This is generalized and the vertical scale is highly exaggerated.

2. SALT MARSH VEGETATION

2. SALT MARSH VEGETATION

Salt marshes are usually described by the types of plants dominating them. To the casual observer, each marsh appears to have only one or two plants growing there. The determining factors in vegetative cover are salinity of the soil and the amount of time or how often that part of the marsh is covered by tide waters. These tides may vary from the regularly occurring lunar tides (twice daily) to those caused by winds. Soil drainage would be another important factor.

To those of us concerned with mosquito and biting fly control the marsh vegetation may take on an entirely new meaning. The importance to us is that vegetative cover reflects the soil type, degree of tidal flooding, salinity, and most important, a good index of the insect pests which could possibly grow there.

For our purposes, we will describe the vegetation in a salt marsh similar to that found on the Newport River basin in Carteret County, North Carolina (see figure). In this area, the water level will change 2 to 3 feet from the average low tide to the average high tide. The lower marsh is completely covered by high tide water twice daily. The upper marsh is covered by tide water only on tides slightly higher than average, 8-20 times each month. Because of the difference in the amount of tidal flooding, the kinds of plants growing there also differs.

The low marsh, or that area covered by tides two times each day is dominated by relatively few different kinds of plants. Most dominant would be cordgrass or Spartina alterniflora (see figure). This plant grows in the areas covered most often by tide water. Near the

margins of the river, ditches or the extreme lower levels of the marsh, the cordgrass will reach 4 to 6 feet high. As you move inward or toward higher levels, the cordgrass will only reach an average height of 1 to 2 feet. The difference in the growth form of cordgrass is apparently due to the flushing action of the tide and the difference in the salt content of the soil.

In the marsh covered by the short Spartina alterniflora, there are several other plants that grow in large numbers but are usually overlooked unless flowering because the cordgrass is taller. The one exception is three-square bulrush or Scirpus robustus (see figure). This plant looks similar to cordgrass in general appearance. The seed head when present makes this plant obviously different from cordgrass. The best method to separate these plants is to feel the stems. Cordgrass has a round stem but as the name implies the stem of three-square bulrush has three flat sides or triangular in cross-section.

The two other plants mixed with the short form cordgrass are Sea-lavender, Limonium carolinianum (see figure) and Saltmarsh aster, Aster tenaifolius (see figure). These two plants at first are easily confused if they are not in flower. Sea-lavender has all of its leaves attached to the base of the plant at ground level. Each leaf has a distinct sharp point at its end. Aster, on the other hand, is similar but each leaf branches off from the stem at a different location and are not basal.

As one progresses inward on the marsh or more correctly, to higher elevations, the dominant vegetation changes. On those higher areas that are not flooded by every high tide, salt grass, Distichlis spicata (see figure), Spartina patens (see figure), and giant cordgrass

Spartina cynosuroides (see figure) become most evident. Giant cordgrass looks similar to Spartina alterniflora except that it grows much taller (8-10 feet), and each leaf will have a shiny midrib not found on S. alterniflora.

Distichlis spicata and Spartina patens look similar in that both have small round stems. Both may grow in very dense mats covering large areas of the marsh. These two may be separated from each other by comparing the pattern in which the leaves branch from the stems. Distichlis branches alternately from the stem forming a large angle (approximately 45^{o}) between the leaf and stem. Spartina patens also is alternate but forms a very close angle (approximately 10 to 15^{o}) between the stem and leaf.

Black needle rush, Juncus roemerianus (see figure) is another plant that occupies the marsh which is only irregularly flooded. Juncus grows to a height of 4 to 5 feet forming a very sharp needlepoint at the end of each stem. As one moves toward higher ground from the marsh, mixed shrubs and hardwoods begin to appear. This is also evident on the spoil piles thrown up by drag lines forming ditches for permanent mosquito control. Small plants most obvious in the marsh edges are:

Sea-ox-eye, Borrichia frutescens (see figure),

Saltwort, Salicornia virginica (see figure),

Marsh-elder, Iva imbricata (see figure), and

Saw grass, Cladium jamaicensis.

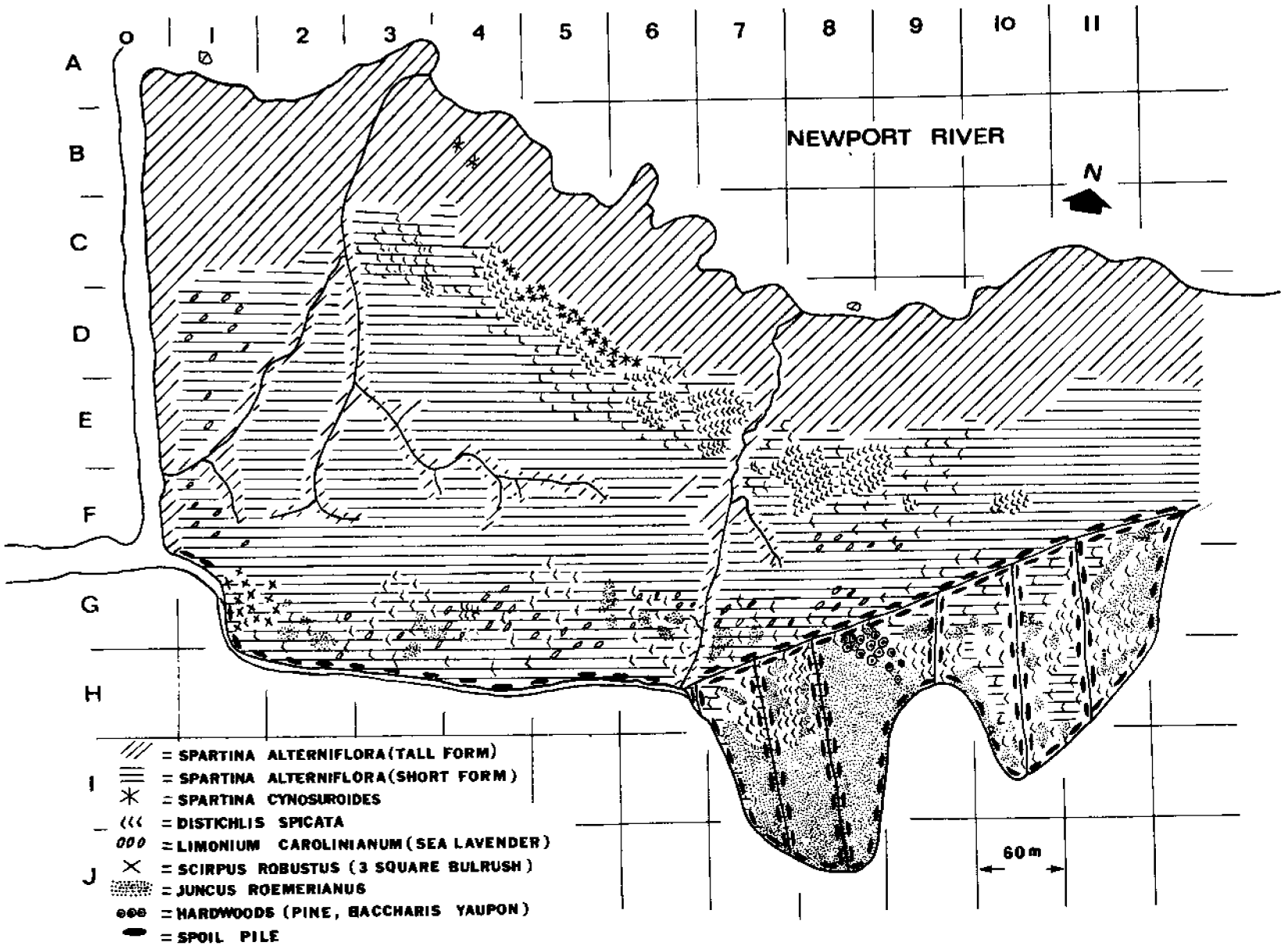
Plants varying from small bushes to large trees are:

Yaupon, Ilex vomitorea

Sea myrtle, Baccharis halimifolia (see figure), and

Wax myrtle, Myrica corifera (see figure).

The wax myrtle was so named because of the very definite fragrance of the leaves. Pine trees and red cedar are also very numerous on spoil piles and the upper margins of the salt marsh.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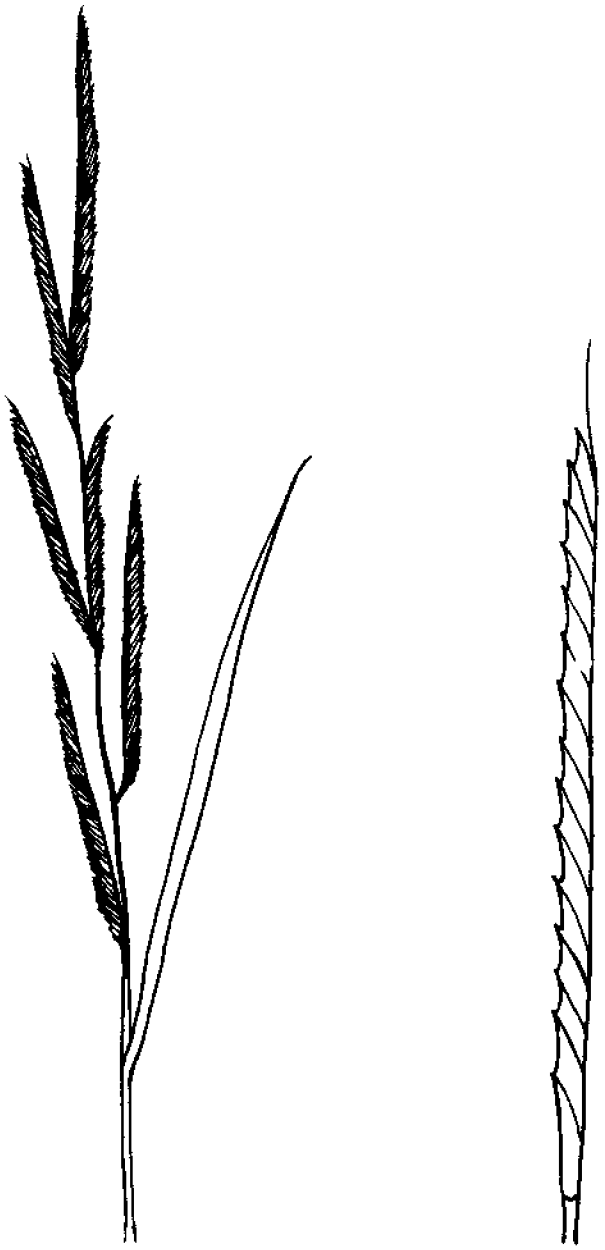
= SPARTINA ALTERNIFLORA (TALL FORM)
= SPARTINA ALTERNIFLORA (SHORT FORM)
= SPARTINA CYNOSUROIDES
= DISTICHLIS SPICATA
= LIMONIUM CAROLINIANUM (SEA LAVENDER)
= SCIRPUS ROBUSTUS (3 SQUARE BULRUSH)
= JUNCUS ROEMERIANUS
= HARDWOODS (PINE, BACCHARIS YAUPON)
= SPOIL PILE



SMOOTH CORDGRASS

Spartina alterniflora

Coastal salt marshes; Washington; Newfoundland to Florida and Texas (the only plant on thousands of acres next to the Atlantic).

Stems from ankle-high where the ground is barely flooded by high tides to higher than a man along marsh creeks. Leaves to 1 1/2 feet long and 3/4 inch wide, long-tapering. Flower clusters to a foot long, usually with long, upright branches. Spikelets similar to those of Big Cordgrass.

THREE-SQUARE BULRUSH

Scirpus robustus (part of Scirpus robustus in Mason's Flora)

Coastal brackish and salt marshes; Washington; California; New Brunswick to Texas.

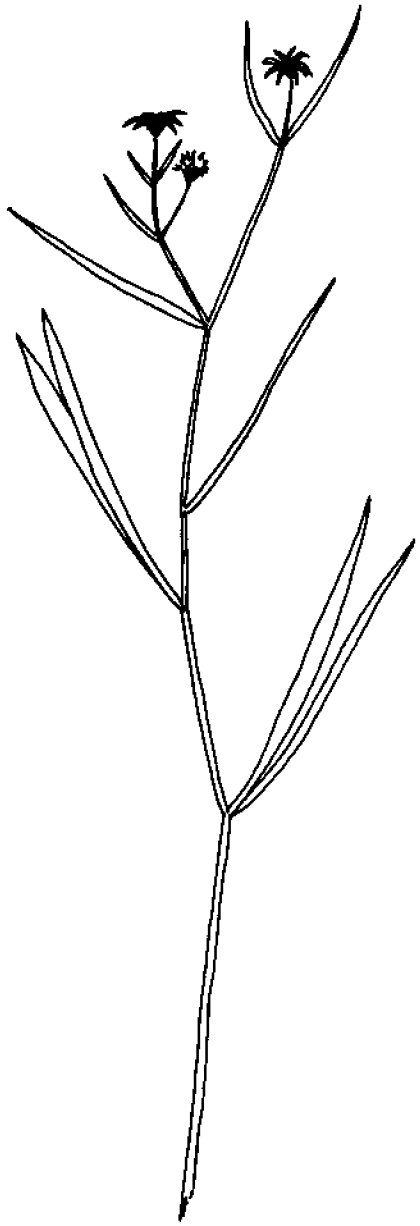
Stems knee-high to shoulder-high. Leaves to 1 1/2 feet long and 3/8 inch wide. Stems triangular in cross-section. Mature spikelets usually reddish-brown, the bristle tips of their scales recurved. Ripe seeds brown, flattish on one side and low-convex on the other in end view.

SEA-LAVENDER

Limonium carolinianum

Coastal salt marshes and rarely inland alkali marshes; California; New Mexico; Newfoundland to Texas.

Flower clusters ankle-high to knee-high, two or three times as high as the leathery leaves. Flowers lavender, 5-petaled, close to each other along the branches.



SALTMARSH ASTER

Aster tenuifolius

Coastal salt and brackish marshes; New Hampshire to Mississippi.

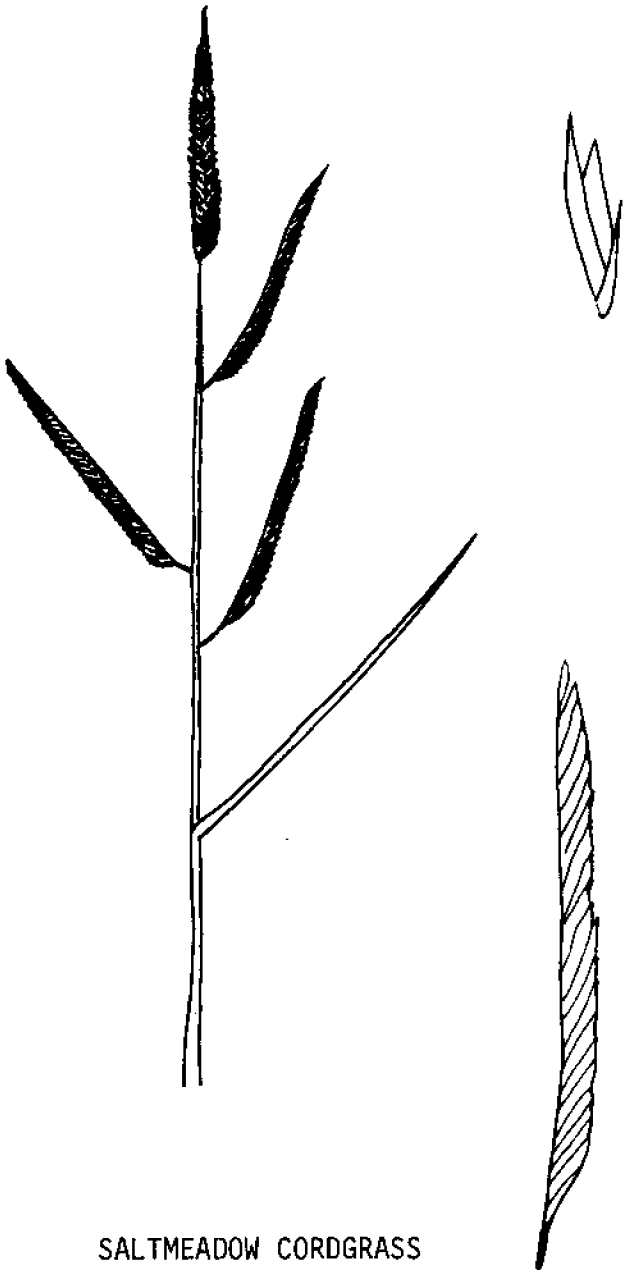
Stems ankle-high to knee-high, branched or unbranched, coming from a perennial rootstock. Leaves to 6 inches long. Flower heads to 3/4 inch across, with bluish or whitish rays.

SALTGRASS

Distichlis spicata

Coastal salt and brackish marshes; British Columbia to California; Nova Scotia to Texas. Inland alkali marshes; British Columbia to Manitoba, California, and Texas.

Stems ankle-high to knee-high. Leaves to 6 inches long and 1/8 inch wide, usually close to each other and standing out from the stem at a wide angle. Flower clusters to 3 inches long. Male spikelets are as much as an inch long and have as many as 20 flowers. Female spikelets are on separate plants, and are shorter and have fewer flowers.

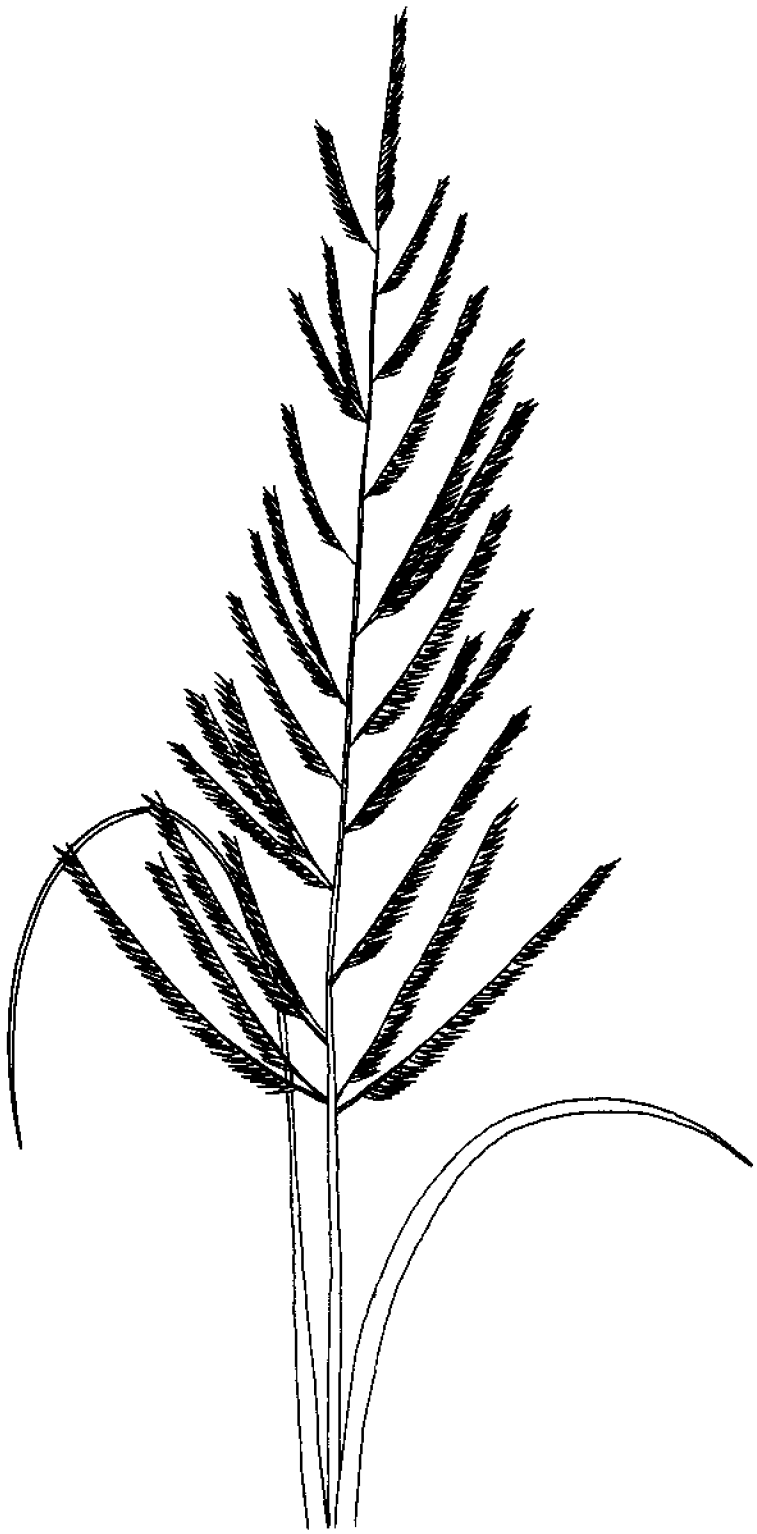


SALTMEADOW CORDGRASS

Spartina patens

Coastal brackish marshes; Newfoundland to Florida and Texas (the principal plant on thousands of acres of meadowlike marsh just above the level of ordinary high tides). Rare in inland brackish marshes in Michigan and New York.

Stems ankle-high to waist-high. Leaves to 1 1/2 feet long and 1/16 inch wide, long tapering. Flower clusters to 8 inches long, usually with 3 to 6 branches. Spikelets similar to those of Big Cordgrass, except usually smaller.



GIANT CORDGRASS

Spartina cynosuroides

Coastal brackish marshes; Massachusetts to Florida and Texas.

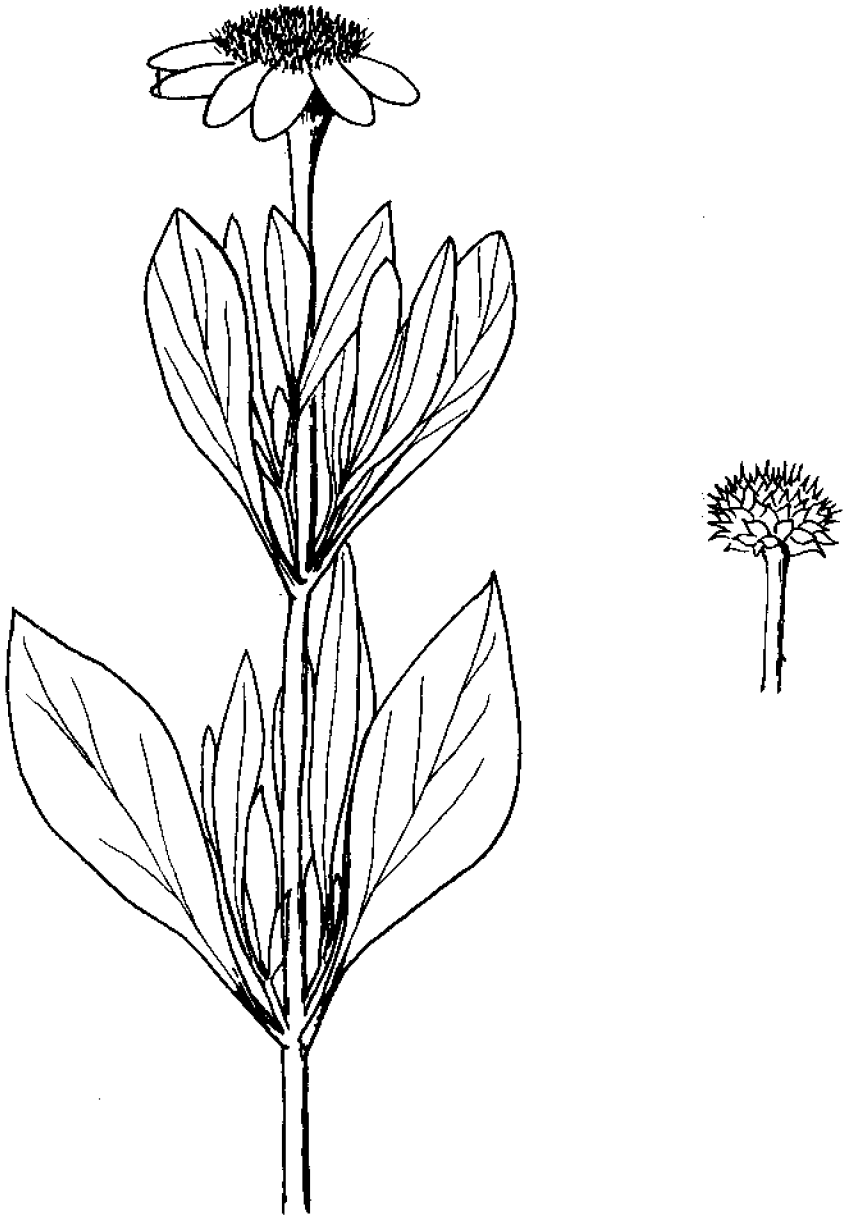
Stems waist-high to half again as high as a man. Leaves to an inch wide. Flower clusters to 1 1/2 feet long, usually with more than 30 branches and with the branches at the top of a cluster usually much shorter than those at the bottom. Spikelets similar to Prairie Cordgrass, except that none of the scales are bristle-tipped.

NEEDLERUSH

Juncus roemerianus

Coastal brackish and salt marshes; Maryland to Texas.

Stems and stemlike leaves knee-high to shoulder-high, usually in dark-green or dark-gray colonies which look about the same the year around. Tips of stems and leaves are so hard and sharp that they often puncture skin. Flower clusters brown. Flowers are in bunches within a cluster.

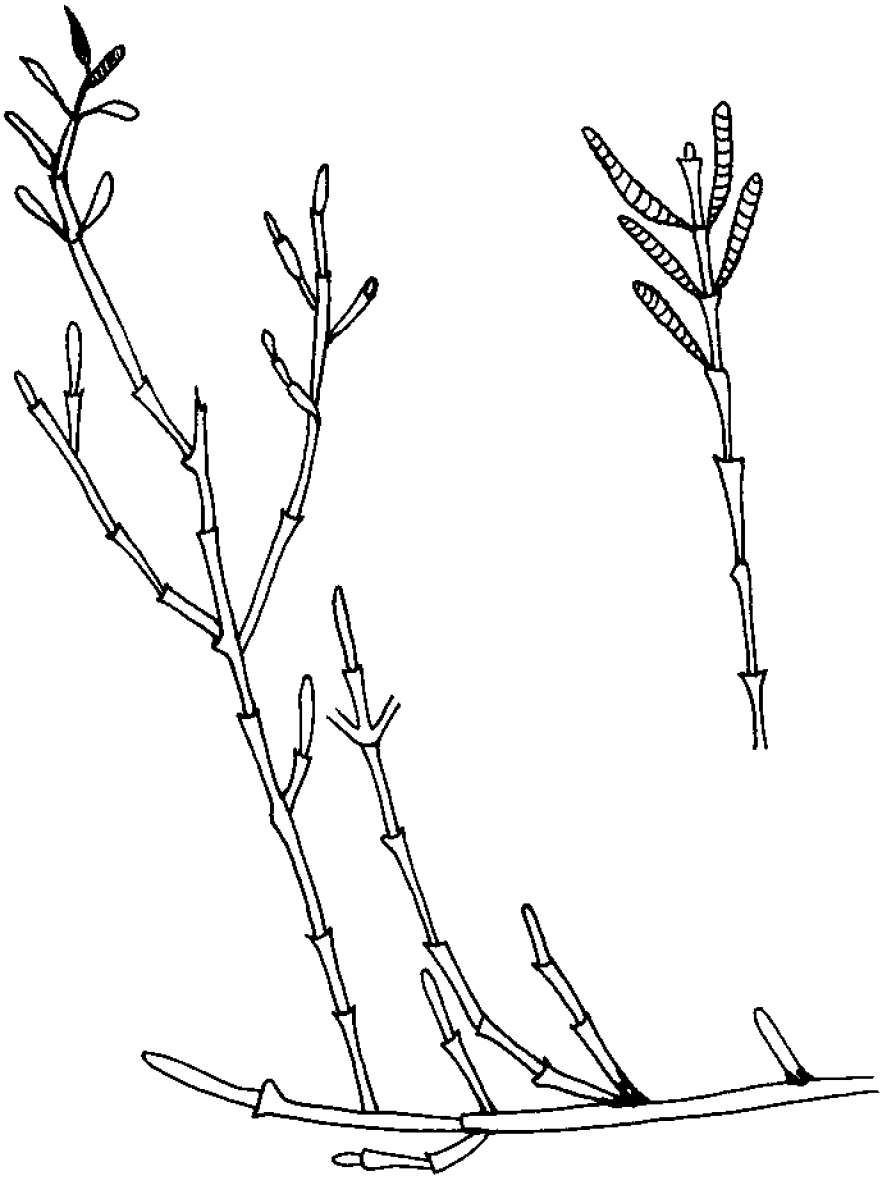


SEA-OXEYE

Borrichia frutescens

Coastal salt marshes; Virginia to Texas.

Stems ankle-high to waist-high, woody, branched, topped with a head of yellow flowers. Leaves grayish, 1 to 4 inches long, their edges untoothed or with little teeth near the base. Seed head burlike because of sharp, hard bracts.



SALTWORT

Salicornia virginica

Coastal salt marshes and rarely inland salt and alkali marshes; Alaska to California and New Mexico; New Hampshire to Texas.

Has rootstocks and often has horizontal main stems. Spikes have nontapering tips with flowers all the way to the end.

MARSH ELDER

Iva imbricata

A low, perennial sub-shrub, sparsely branched with semi-woody stems. It grows upright from 1 to 3 1/2 feet high. The leaves and stems are smooth and without pubescence. The fleshy leaves are shaped with the edges smooth or sometimes slightly toothed.

SAWGRASS

Cladium jamaicense

Inland and coastal fresh marshes; California through the southern border states to Virginia.

Stems waist-high to half again as high as a man. Leaves to 6 feet long and 3/8 inch wide, their edges very rough when rubbed downward. Flower clusters to 3 feet long. Mature spikelets brown. Ripe seeds brown, roundish in end view.

SEA MYRTLE

Baccharis halimifolia

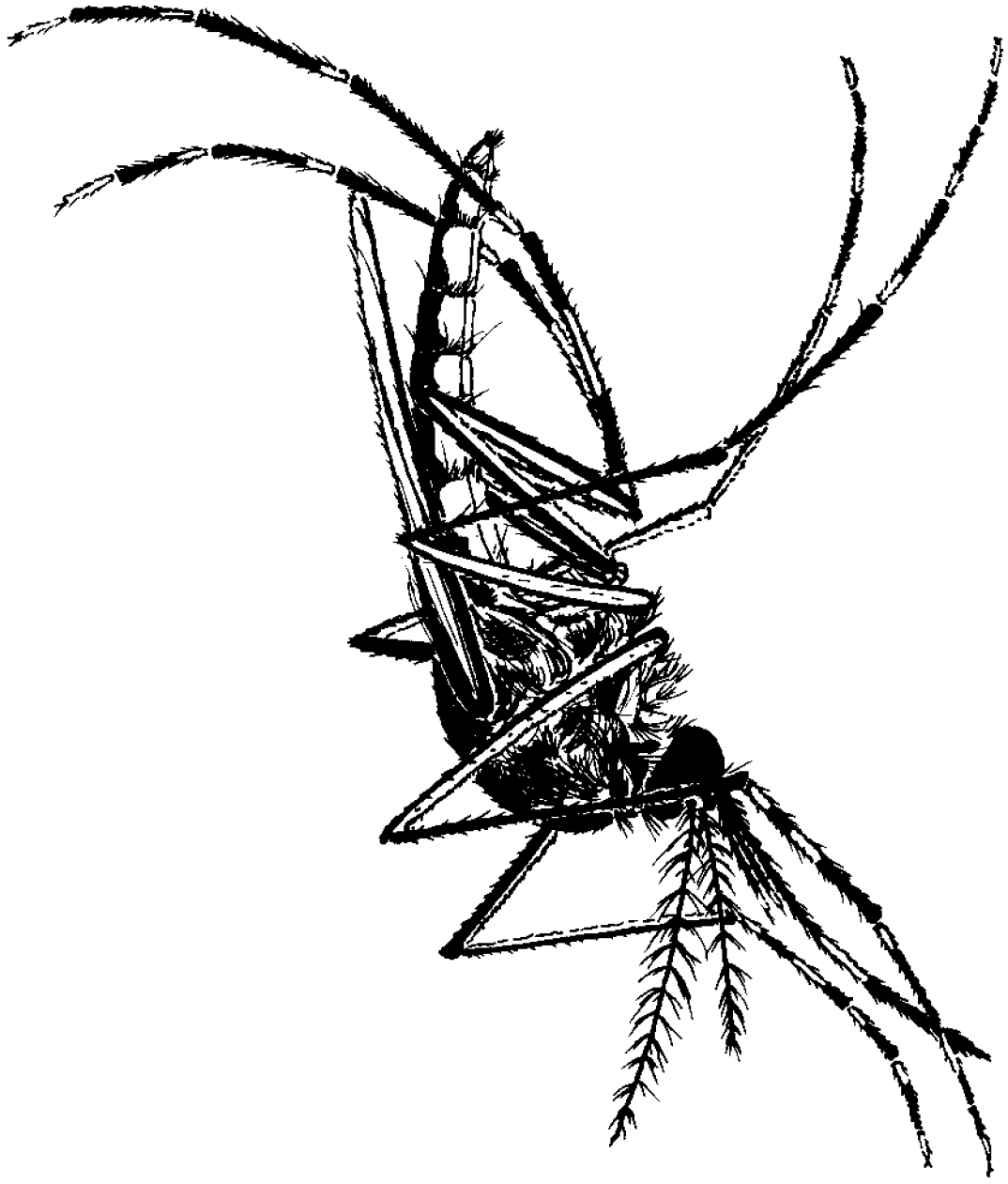
Baccharis is an open-growing brittle-branched, weedy shrub 3 to 11 feet tall. The leaves are thickened and coarsely toothed mostly toward the apex. A silvery sheen of fluffy, white flowers bloom and ripen in late fall. The leaves are poisonous. This shrub prefers moist areas and is found mostly in the marshes and near the shorelines of sounds and estuaries.

WAX MYRTLE

Myrica cerifera

Wax myrtle is an evergreen shrub usually 8 to 10 feet tall. The leaves are leathery, yellowish green in color, and have a fresh aromatic odor when crushed. The plant prefers moist locations which have a high water table.

3. MOSQUITOES



AEDES MOSQUITO

3. MOSQUITOES

3.1 BIOLOGY AND LIFE CYCLE

Mosquitoes undergo complete metamorphosis or more simply stated, have four distinct stages in their life history: egg, larva, pupa, and adult. All of these stages occur in water except the adult. A few of the differences of these four stages between the Anopheles, Aedes and Culex mosquitoes are shown in Figure 1.

Eggs. When first deposited by the female mosquito, the eggs are whitish in color but turn dark after one or two hours. The different genera of mosquitoes have different egg laying habits. The Anopheline mosquito lays her eggs individually on the surface of water. The eggs are elongate, oval pointed at one end and have a pair of floats. Culex mosquitoes lay their eggs side by side forming a floating raft of eggs. These rafts float about on the surface of the water until they hatch.

Female mosquitoes belonging to such genera as Aedes and Psorophora lay their eggs individually on moist soil, not on the surface of standing water. Because these eggs are placed out of water, they must be able to withstand long periods of drying or freezing until such time that they are flooded by water. Our common salt-marsh mosquitoes, Aedes sollicitans and Aedes taeniorhynohus are in this group.

Larvae. All mosquito larvae are aquatic with different species preferring different types of water. Some species live mostly in salt marshes, others in permanent ponds, temporary flood waters, tree holes, or artificial containers. The larval stage includes four developmental stages or instars usually requiring from 4 to 10 days for completion. Figure 2 shows the general morphology of mosquito larvae.

Anopheline larvae characteristically assume a resting position parallel to the surface of the water. The larvae of other genera hang head down with only the tip of an air tube penetrating the surface of the water. Anopheles have no obvious air tube, Aedes have a short stout air tube with only one tuft of hairs about midway of the tube. Culex larvae have a long air tube with several tufts of hair along the side.

Pupae. The fourth larval instar molts into a pupae which differs drastically from the larval instars. The pupae are aquatic but are non-feeders. The head and thorax make up most of the body. The air tubes are on the top of the thorax of the pupal stage. Differences in the pupal stages of the three genera are less noticeable than in other stages.

Adult. The adult mosquitoes are small fragile insects having three body regions (head, thorax and abdomen). The adult is the only stage that is not aquatic. The female mosquito normally seeks out a blood meal and then rests for a time before seeking a suitable place to deposit her eggs. The male mosquitoes do not take a blood meal but obtains their nutrition from plants.

3.2 IDENTIFICATION

Common genera. The adult females of the three genera may be separated by a few general characteristics. Female Anopheles have palpi which are about the same length as the proboscis or piercing mouth parts. The wings are heavily scaled and pigmented or marked. She normally rests with her head pointed down and the end of the abdomen pointed more or less straight up.

Adult female Aedes have short palpi about one-third the length of the probosics, the wings lack spots and the abdomen is pointed. Culex females also have short palpi and clear wings but the end of the abdomen is usually retracted and appears blunt.

Common species. There are approximately six species of mosquitoes belonging to the genera Anopheles, Aedes, Psorophora, and Culex that are most common among the many species of mosquitoes in the coastal area of North Carolina. The many other mosquitoes occur regularly in small numbers and on occasion may dominate in an area for a short period of time. Proper identification of all the different species of mosquitoes requires considerable experience with mosquito keys and the use of a microscope. Even then, the adult mosquitoes must be in near perfect condition.

We will confine our identification to some tips on how to recognize the major pests in the coastal area. We will consider only the major characteristics which will enable a worker to recognize the common species with the aid of a hand lens. Caution. Remember that we are only presenting the common species and on occasion other species may occur which very closely resemble these common ones. In those cases, the assistance of a specialist in mosquito identification should be obtained.

First, we should be very familiar with the parts of the body of an adult mosquito (Figure 3). Like all other insects, the mosquito has three body regions each bearing certain appendages. The head contains the eyes, mouth parts or probosis, the antennae, and the maxillary palpi. The thorax has three segments each bearing one pair of legs. The second segment contains the wings. The third

segment bears the halters or redimentary second pair of wings. The abdomen is segmented and terminates into a pair of cerci which may or may not be visible.

Figures* of the common adult female mosquitoes are included with key characters for recognition indicated. These characters are usually visible with the naked eye on good specimens although a hand lens should be used. The shape, length, and color pattern of the various parts of the adult mosquito will enable a person to separate one mosquito from another, to a limited degree. The experienced taxonomists would consider many more characters that are visible only with the use of a microscope.

Also following are figures of the larvae of the six most common mosquitoes occurring in the coastal area of North Carolina. The figures also have particular characteristics pointed out that should enable a worker to separate one species from another. These drawings illustrate how difficult it is to be certain of the species of a larva you collect. Differences between genera (Aedes, Culex, etc.) are much more obvious. A microscope and slide-mounted specimens are required for adequate identification of the species.

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*Figures reproduced, by permission of the University of California Press, from "Mosquitoes of North America" by S. J. Carpenter and W. J. LeCasse. 1955.

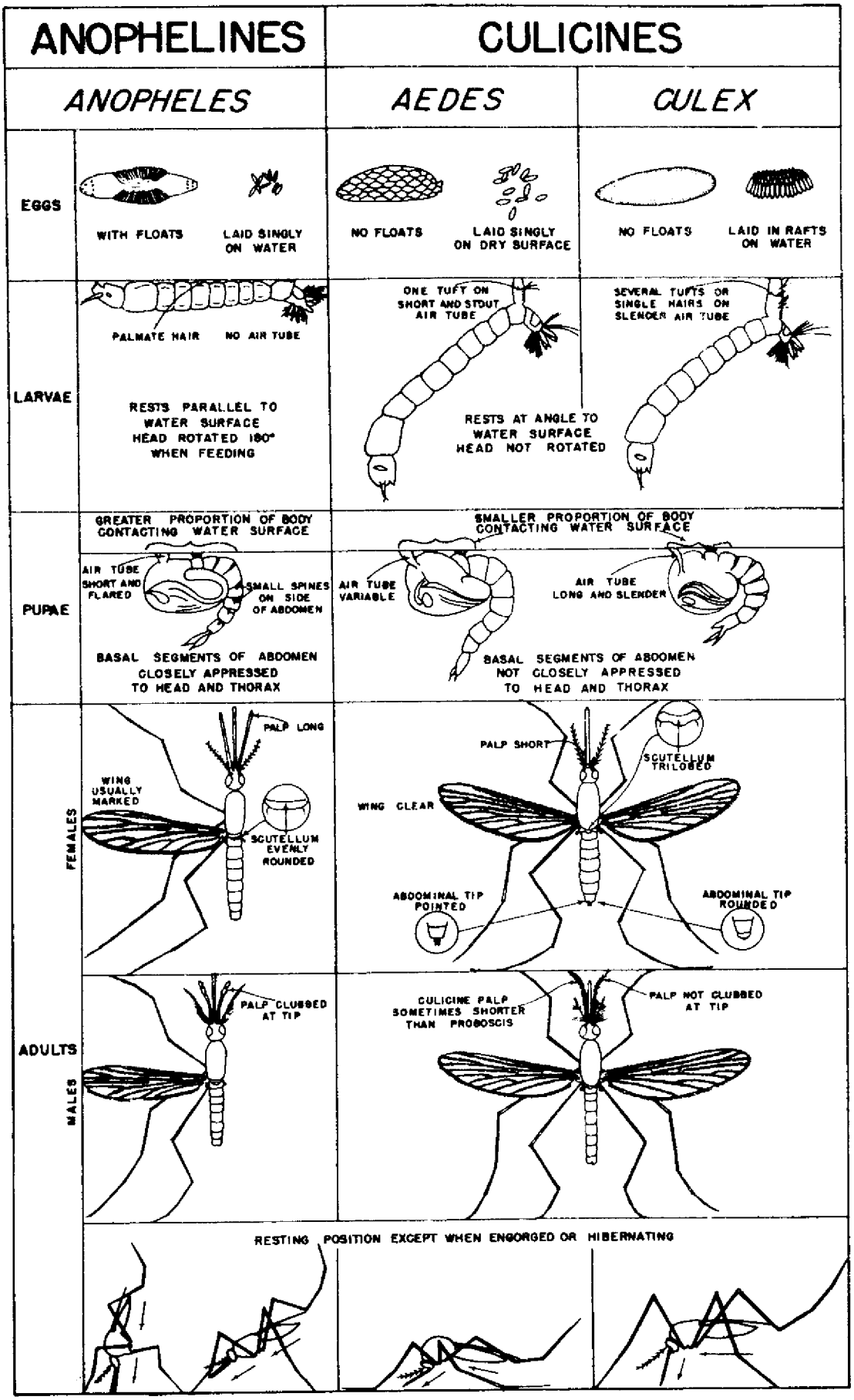
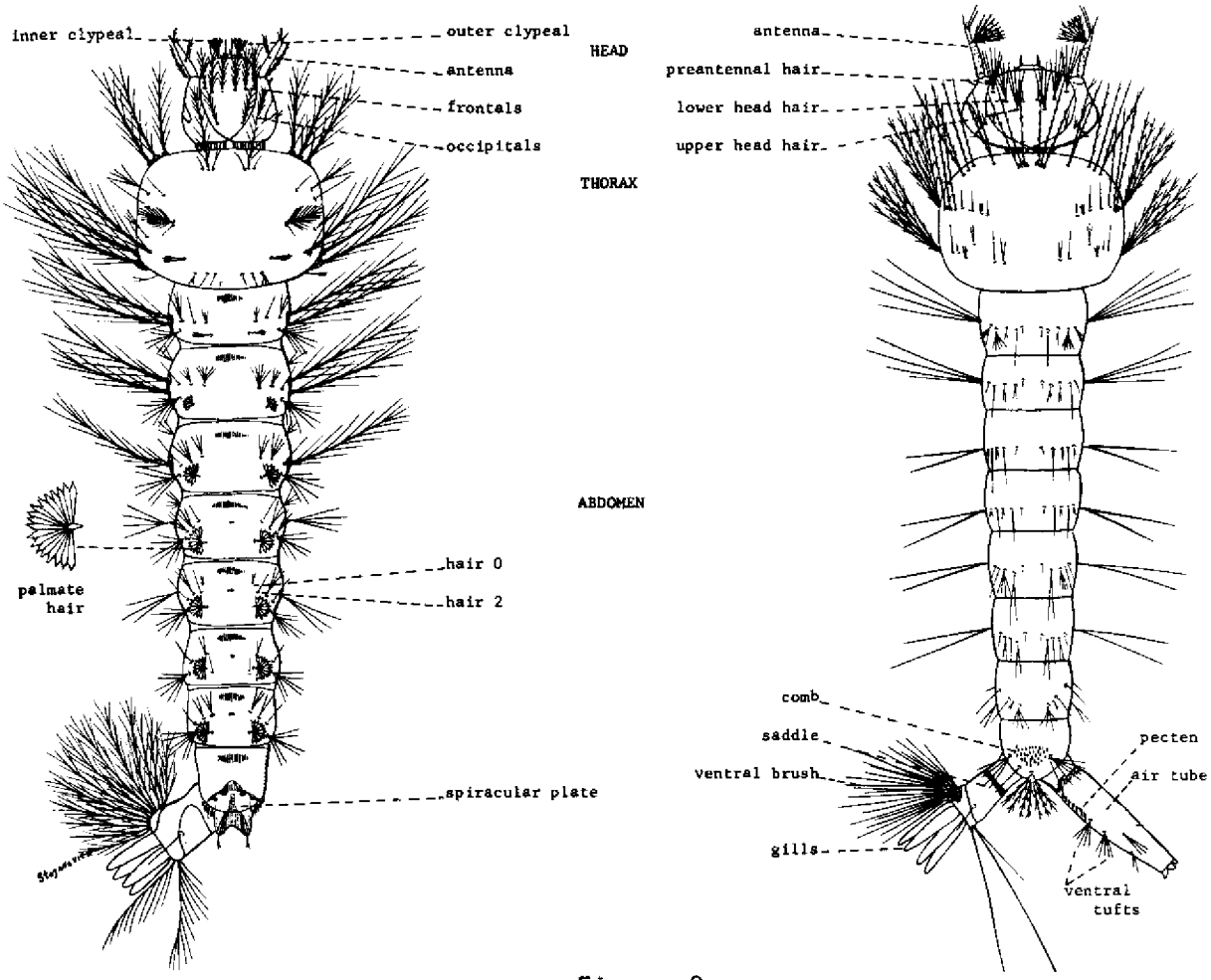

ANOPHELINES
CULICINES
ANOPHELES
AEDES
CULEX
EGGS
WITH FLOATS
LAID SINGLY ON WATER
NO FLOATS
LAID SINGLY ON DRY SURFACE
NO FLOATS
LAID IN RAFTS ON WATER
LARVAE
PALMATE HAIR
NO AIR TUBE
RESTS PARALLEL TO WATER SURFACE HEAD ROTATED 180° WHEN FEEDING
ONE TUFT ON SHORT AND STOUT AIR TUBE
RESTS AT ANGLE TO WATER SURFACE HEAD NOT ROTATED
SEVERAL TUFTS OR SINGLE HAIRS ON SLENDER AIR TUBE
PUPAE
GREATER PROPORTION OF BODY CONTACTING WATER SURFACE
AIR TUBE SHORT AND FLARED
SMALL SPINES ON SIDE OF ABDOMEN
BASAL SEGMENTS OF ABDOMEN CLOSELY APPRESSED TO HEAD AND THORAX
SMALLER PROPORTION OF BODY CONTACTING WATER SURFACE
AIR TUBE VARIABLE
AIR TUBE LONG AND SLENDER
BASAL SEGMENTS OF ABDOMEN NOT CLOSELY APPRESSED TO HEAD AND THORAX
ADULTS
FEMALES
PALP LONG
WING USUALLY MARKED
SCUTELLUM EVENLY ROUNDED
PALP SHORT
SCUTELLUM TRILOBED
WING CLEAR
ABDOMINAL TIP POINTED
ABDOMINAL TIP ROUNDED
MALES
PALP CLUBBED AT TIP
CULICINE PALP SOMETIMES SHORTER THAN PROBOSCIS
PALP NOT CLUBBED AT TIP
RESTING POSITION EXCEPT WHEN ENGORGED OR HIBERNATING

Figure 1



ANOPHELES LARVA

Figure 2

CULEX LARVA

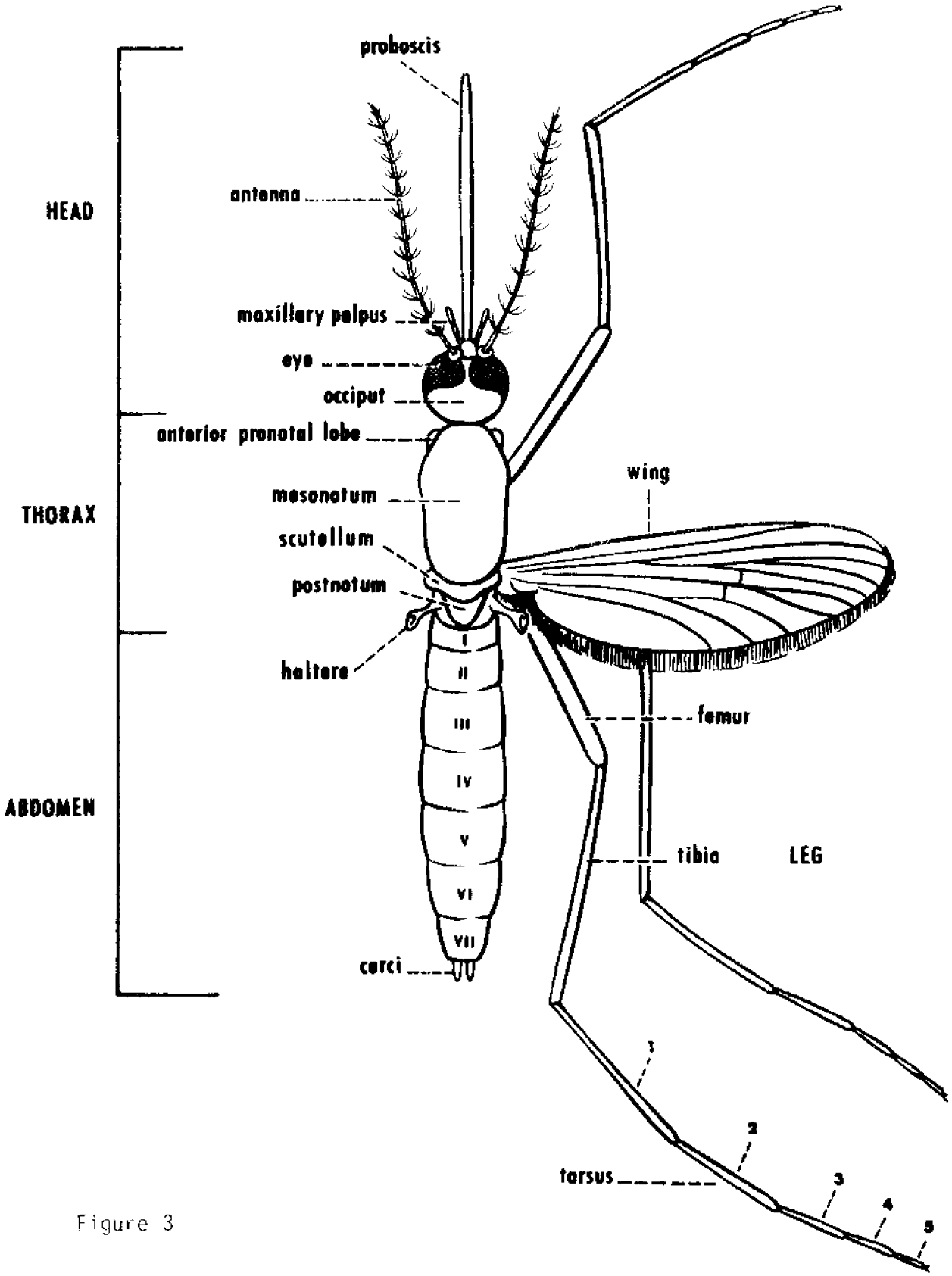
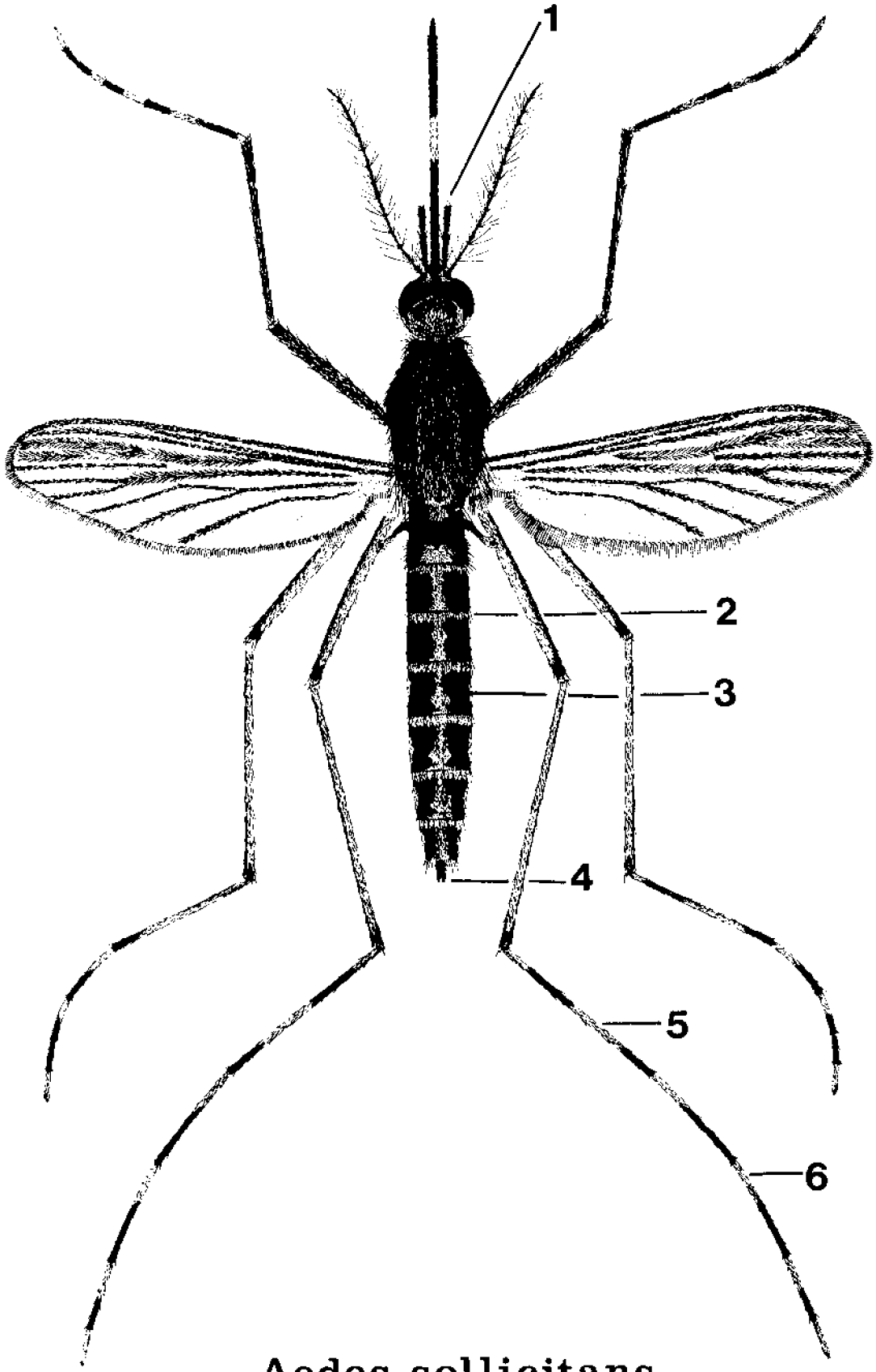

proboscis
antenna
HEAD
maxillary palpus
eye
occiput
anterior pronotal lobe
THORAX
mesonotum
scutellum
postnotum
wing
haltere
I
II
III
IV
V
VI
VII
cerci
ABDOMEN
femur
tibia
LEG
1
2
3
4
5
tarsus

Figure 3

Aedes sollicitans

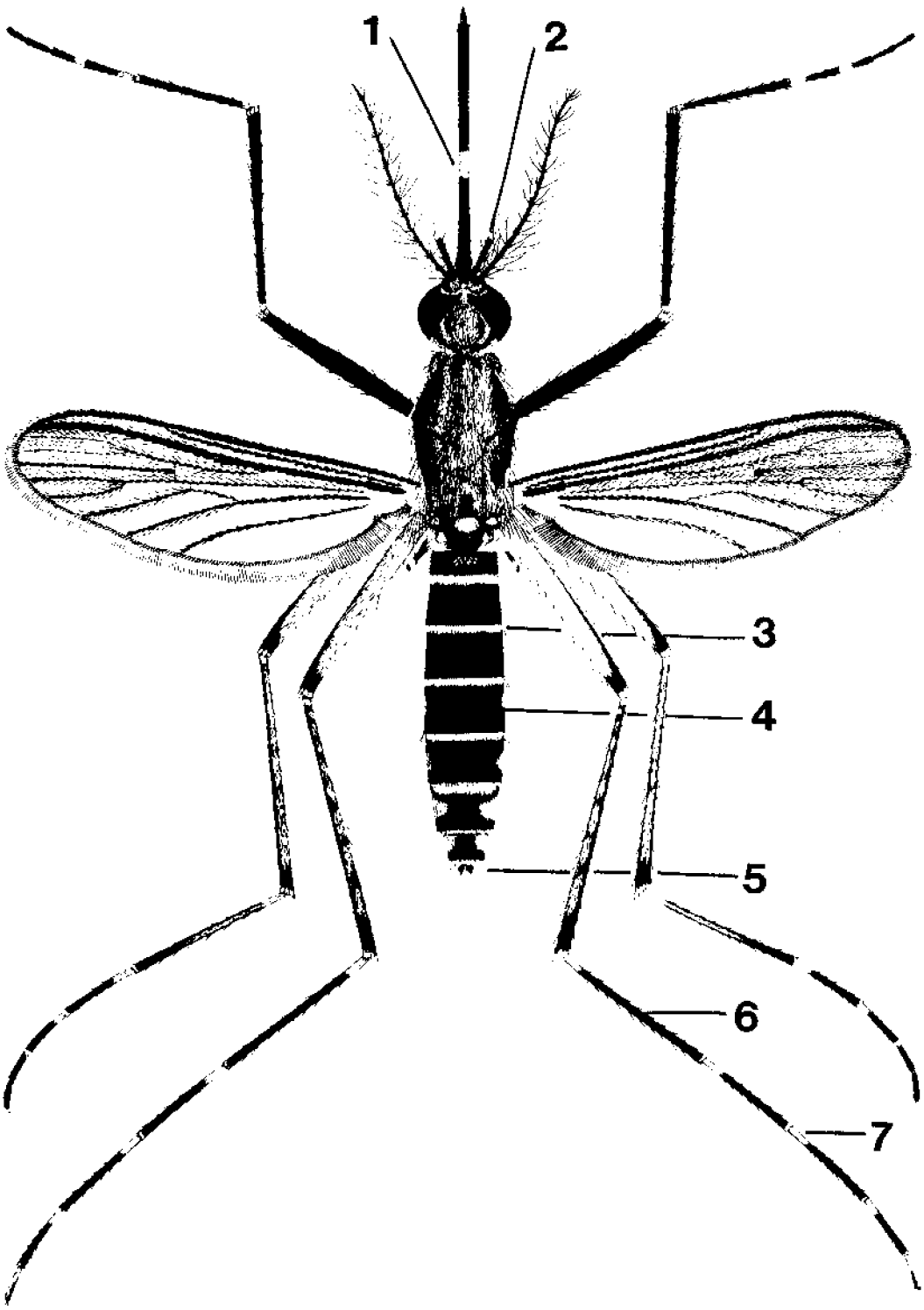
1. Palpi much shorter than probosis
2. Abdomen banded basally
3. Upper surface of abdomen with a longitudinal stripe
4. Abdomen pointed at tip
5. First segment of hind tarsi with a ring at middle of segment
6. Hind tarsi ringed with white bands (wide)



Aedes sollicitans

Aedes taeniorhynchus

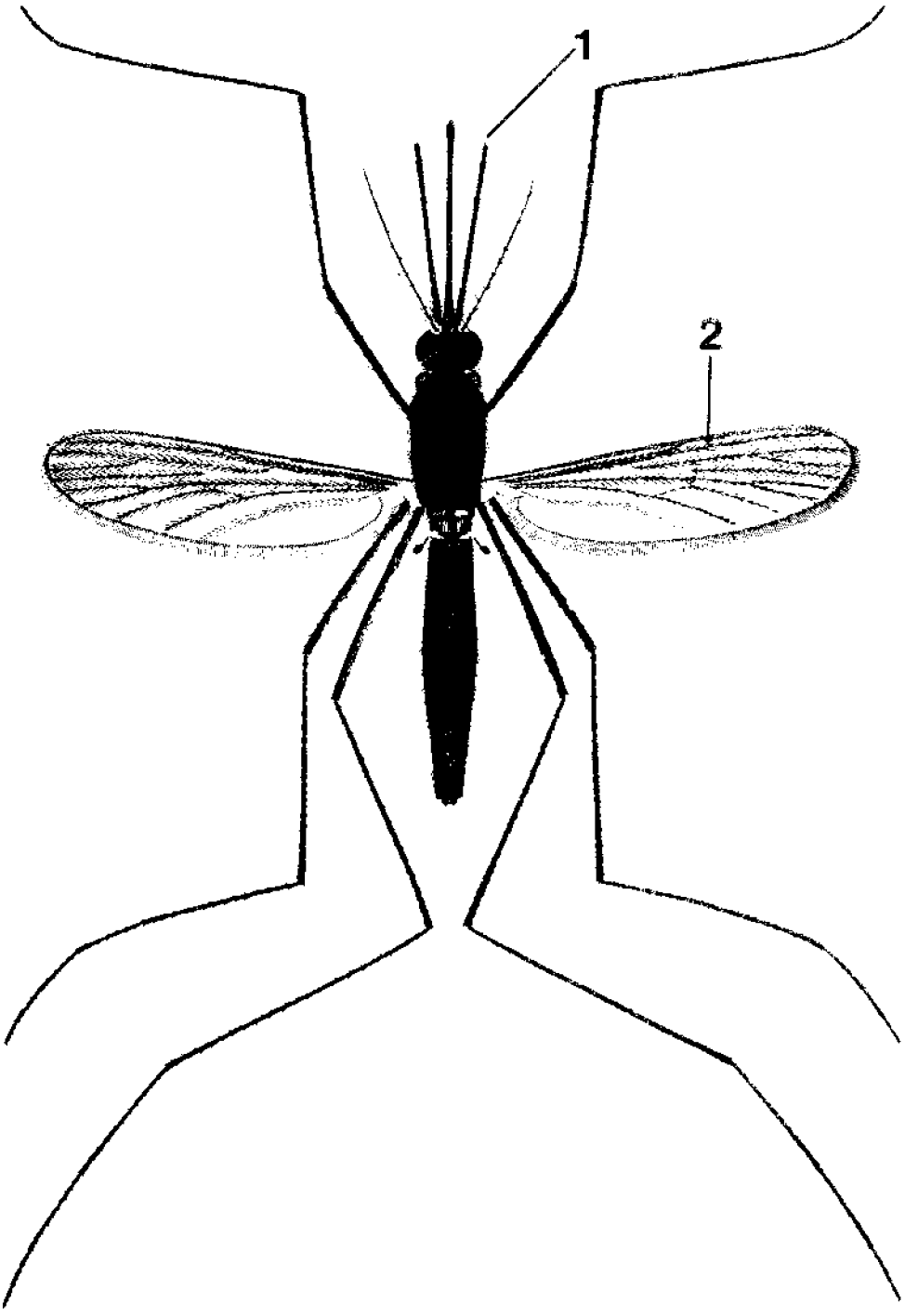
1. Probosis with white band
2. Palpi much shorter than probosis
3. Abdomen banded basally
4. No longitudinal stripe down middle of abdomen
5. Abdomen pointed at tip
6. No white band in middle of first hind tarsal segment
7. Hind tarsi ringed with narrow white bands



Aedes taeniorhynchus

Anopheles atropos

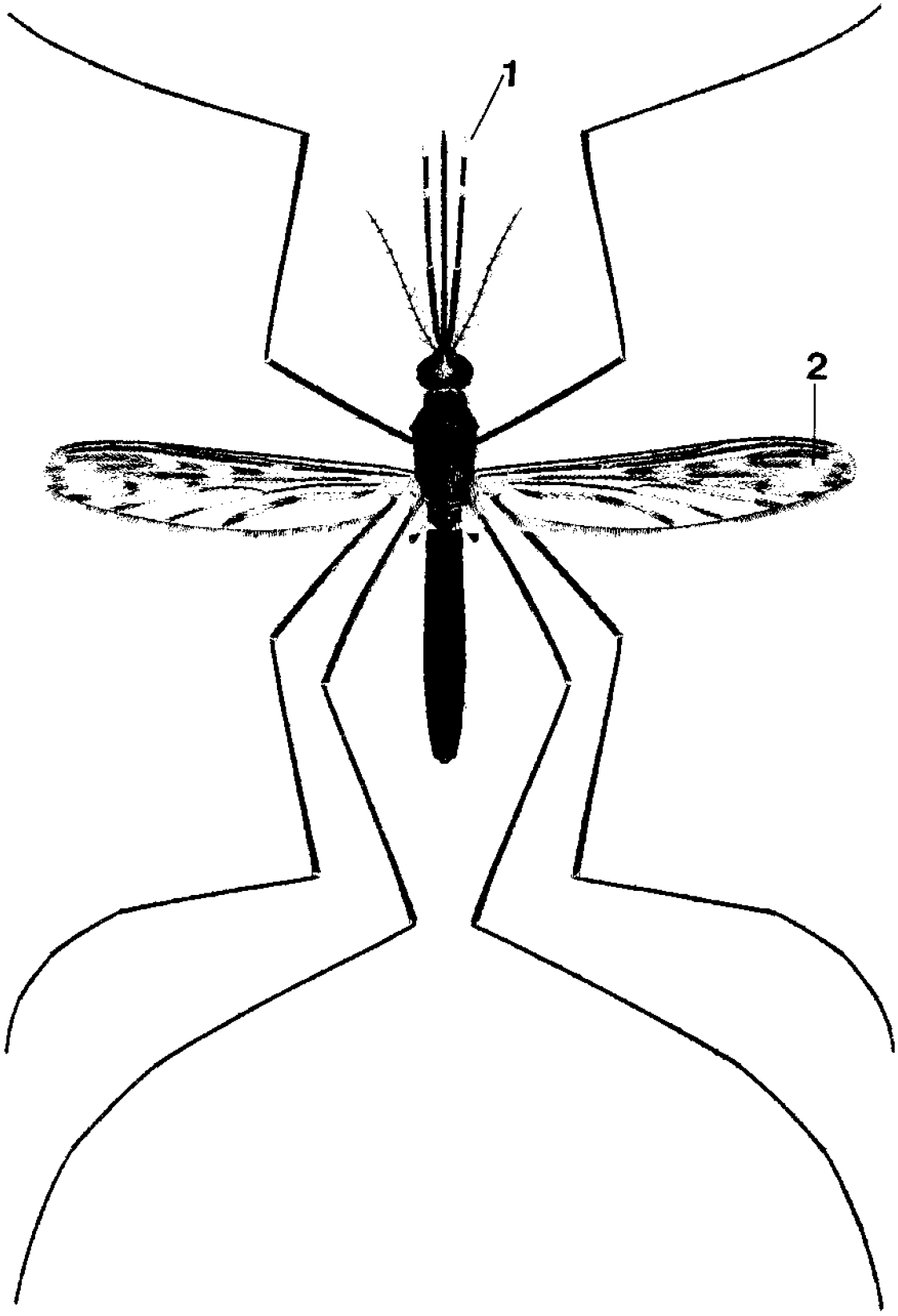
1. Palpi about as long as probosis
2. Wings with all dark scales, no spotting



Anopheles atropos

Anopheles bradleyi

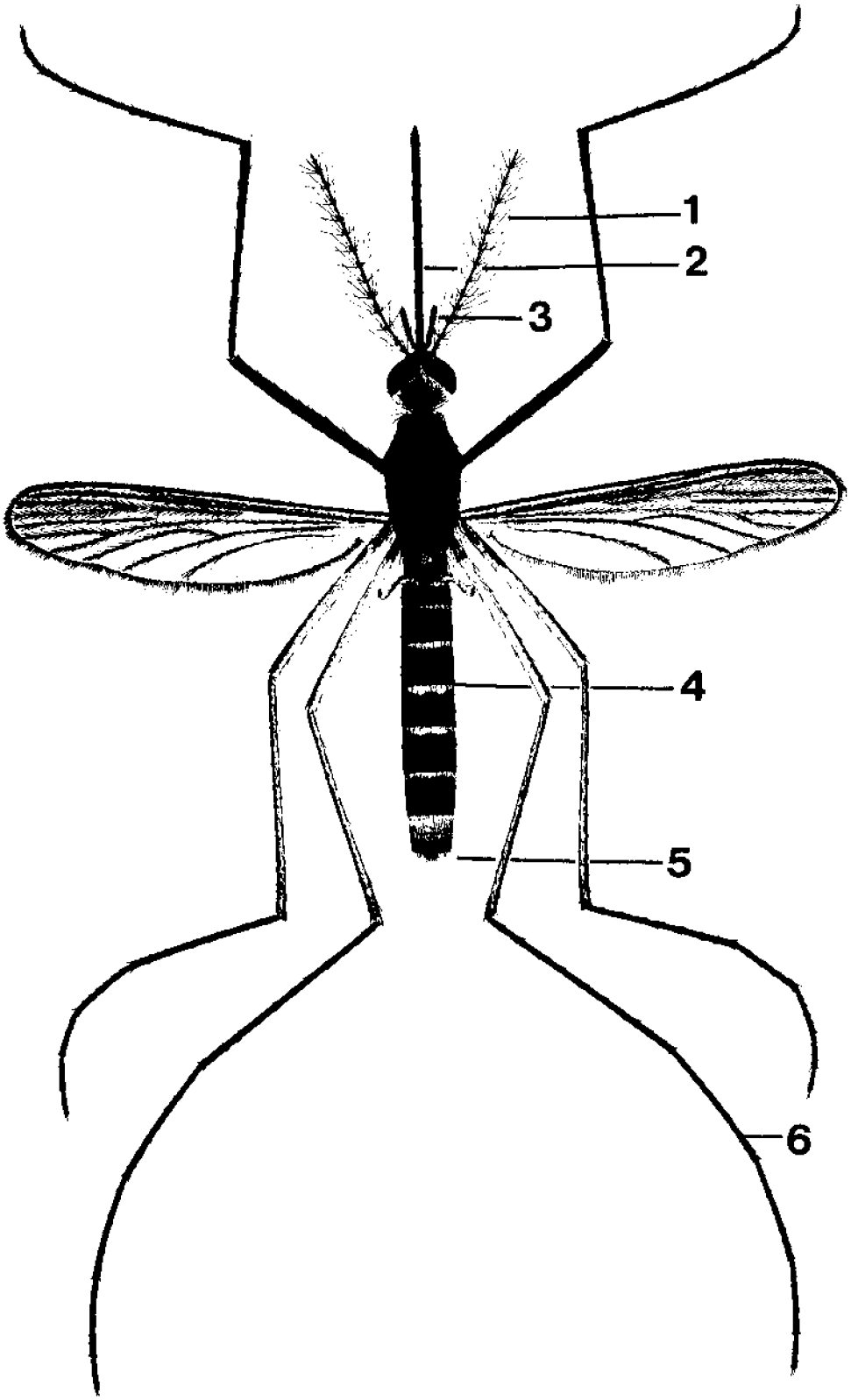
1. Palpi about as long as probosis
2. Wings with patches of white scales



Anopheles bradleyi

Culex salinarius

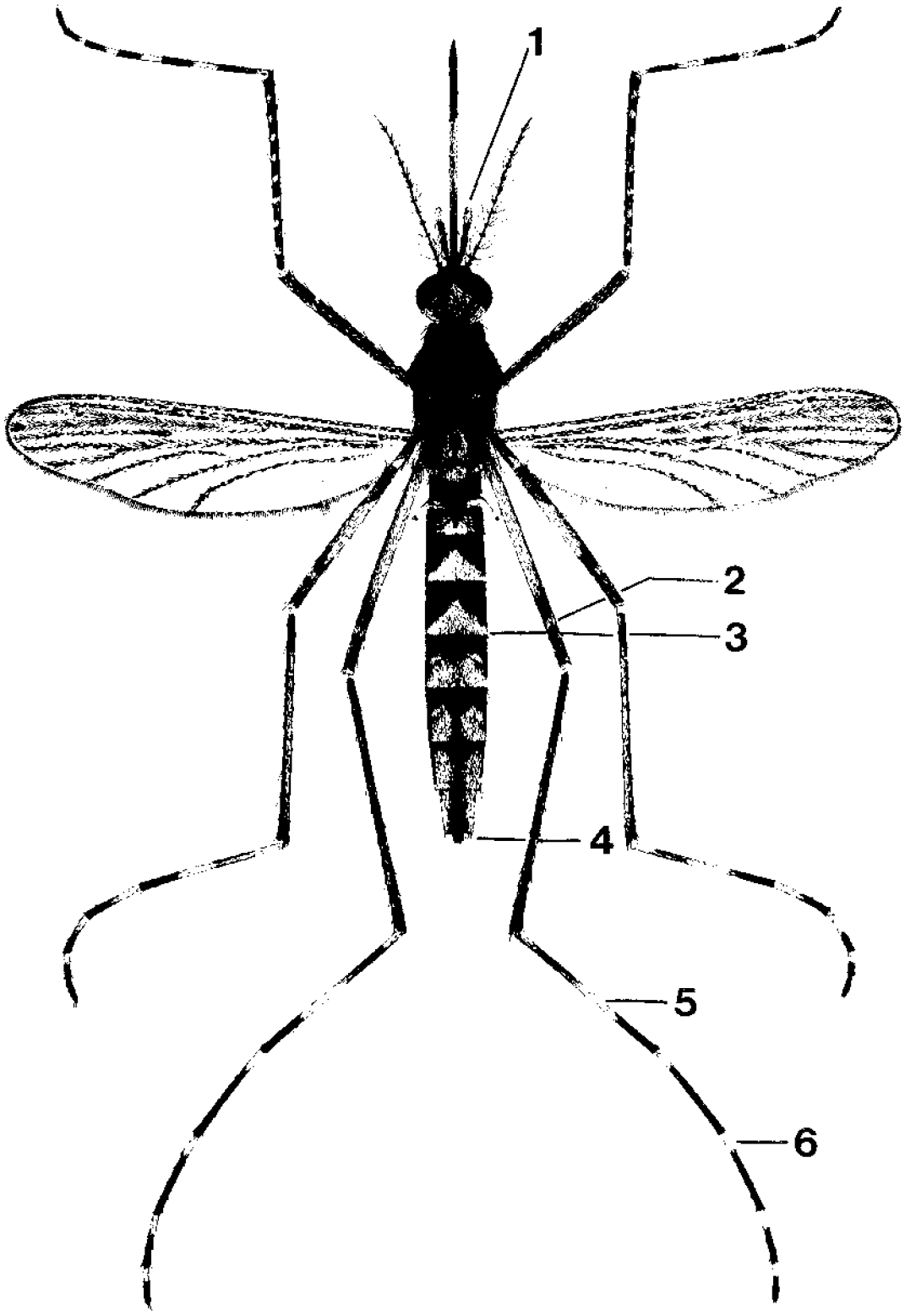
1. Antenna not longer than probosis
2. Probosis not banded
3. Palpi much shorter than probosis
4. Abdominal tergites with narrow bands at base
5. Abdomen blunt at tip
6. Tarsi not banded



Culex salinarius

Psorophora confinnis

1. Palpi much shorter than probosis
2. Hind femur with narrowing at apex
3. Abdomen banded apically
4. Abdomen pointed at tip
5. First segment of hind tarsus with a definite ring at middle
6. Hind tarsi ringed with white bands



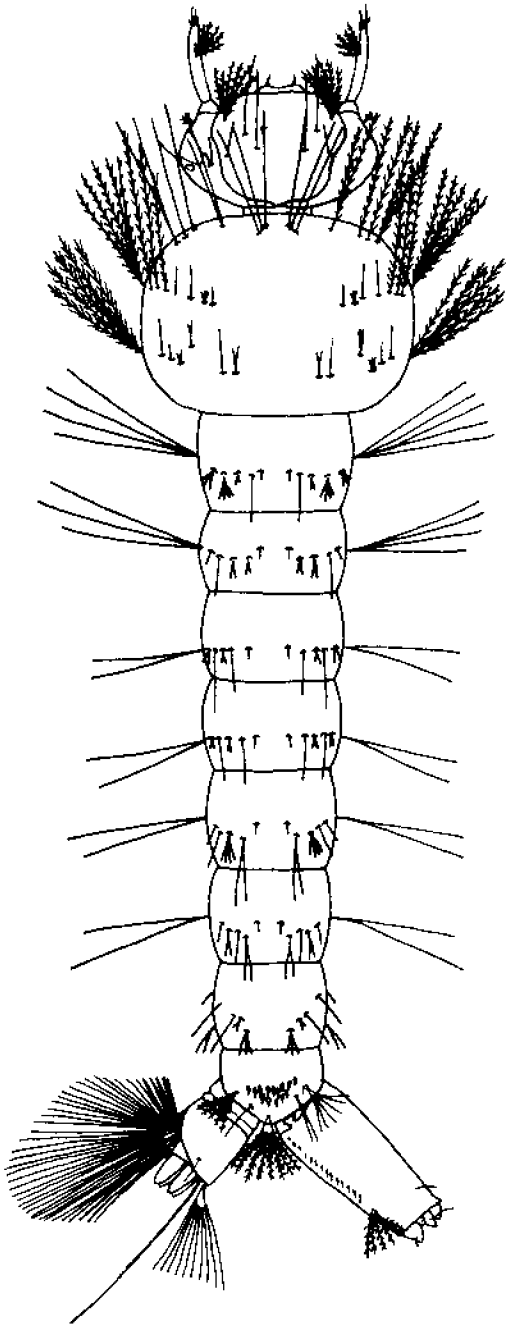
Psorophora confinnis

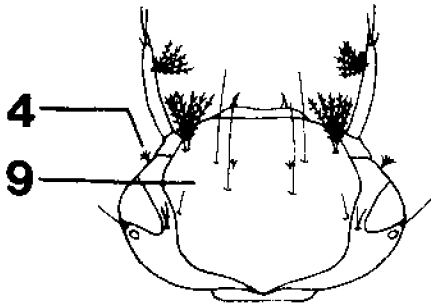
NOTES

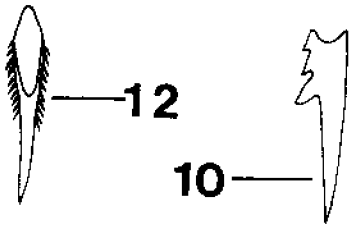
NOTES

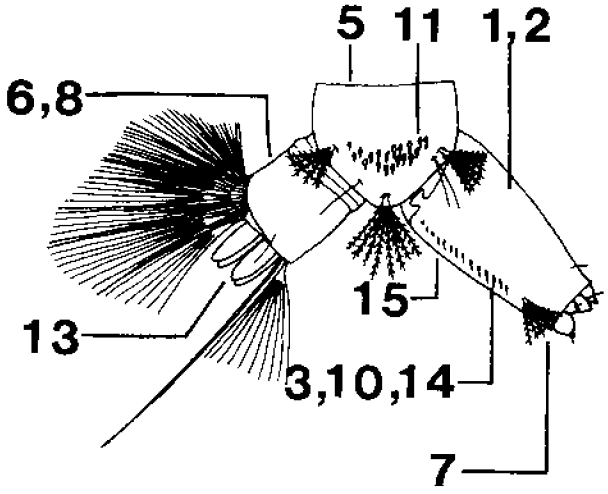
Aedes sollicitans

1. Respiratory siphon present
2. Siphon gradually narrowing apically or broadening, not for piercing plant tissue
3. Siphon with pecten teeth
4. Head wider than long
5. Abdominal segment VIII without plate
6. Anal segment with a single sclerotized plate
7. Siphon with but a single pair of hairs ventro-laterally or laterally
8. Anal segment ringed by saddle and ventral brush confined to area posterior to it
9. Either upper or lower head hair single, usually both single
10. Pecten with teeth rather evenly spaced
11. Comb with more than 12 scales in 2-3 rows or patch, each scale thorn-shaped or with subequal spinules
12. Comb scales thorn-shaped, or apical spine twice or more as long as those on either side
13. Anal gills shorter than anal segment
14. Pecten reaching middle of siphon or beyond
15. Siphonal index 2.0-2.5





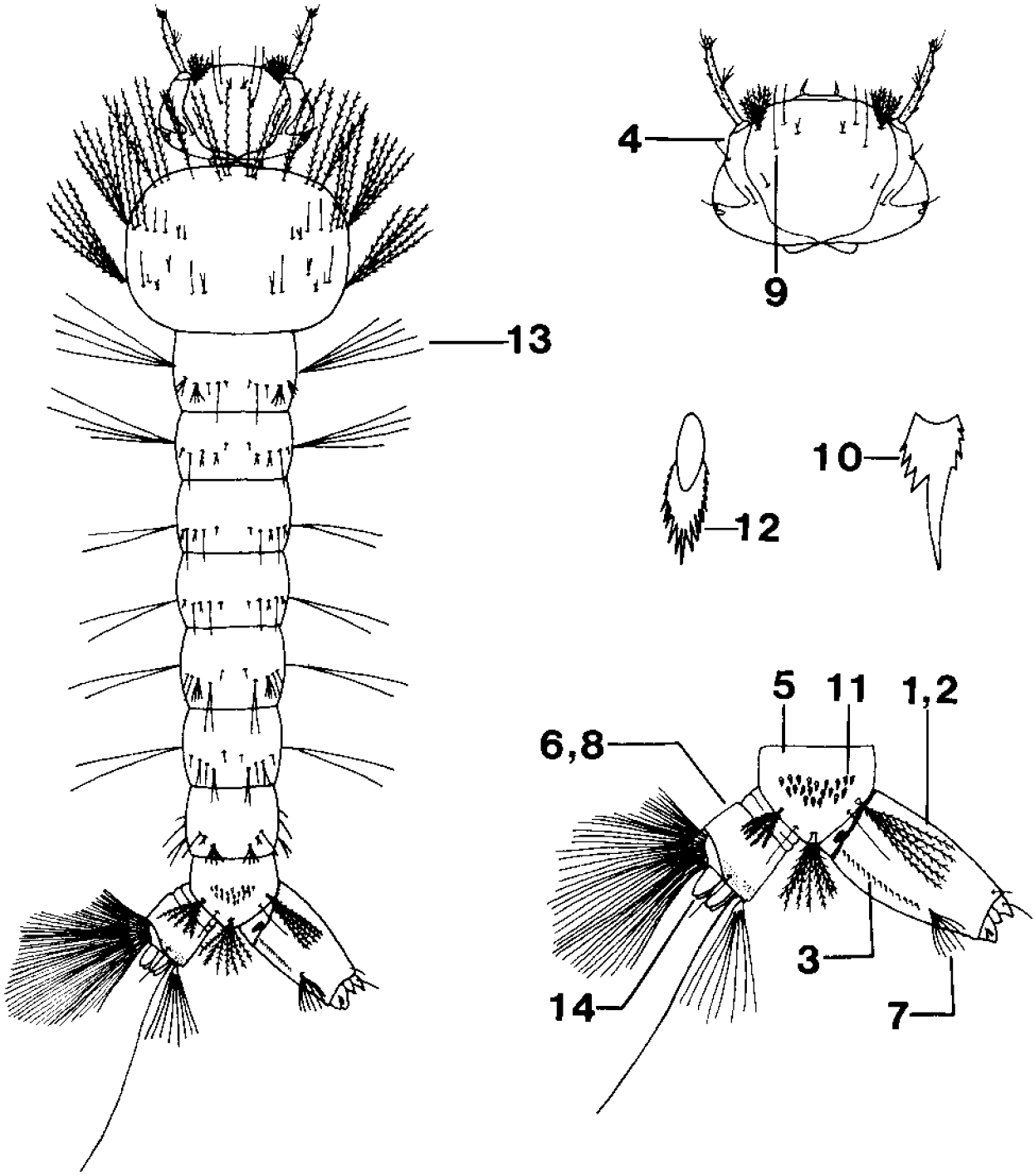




Aedes sollicitans

Aedes taeniorhynchus

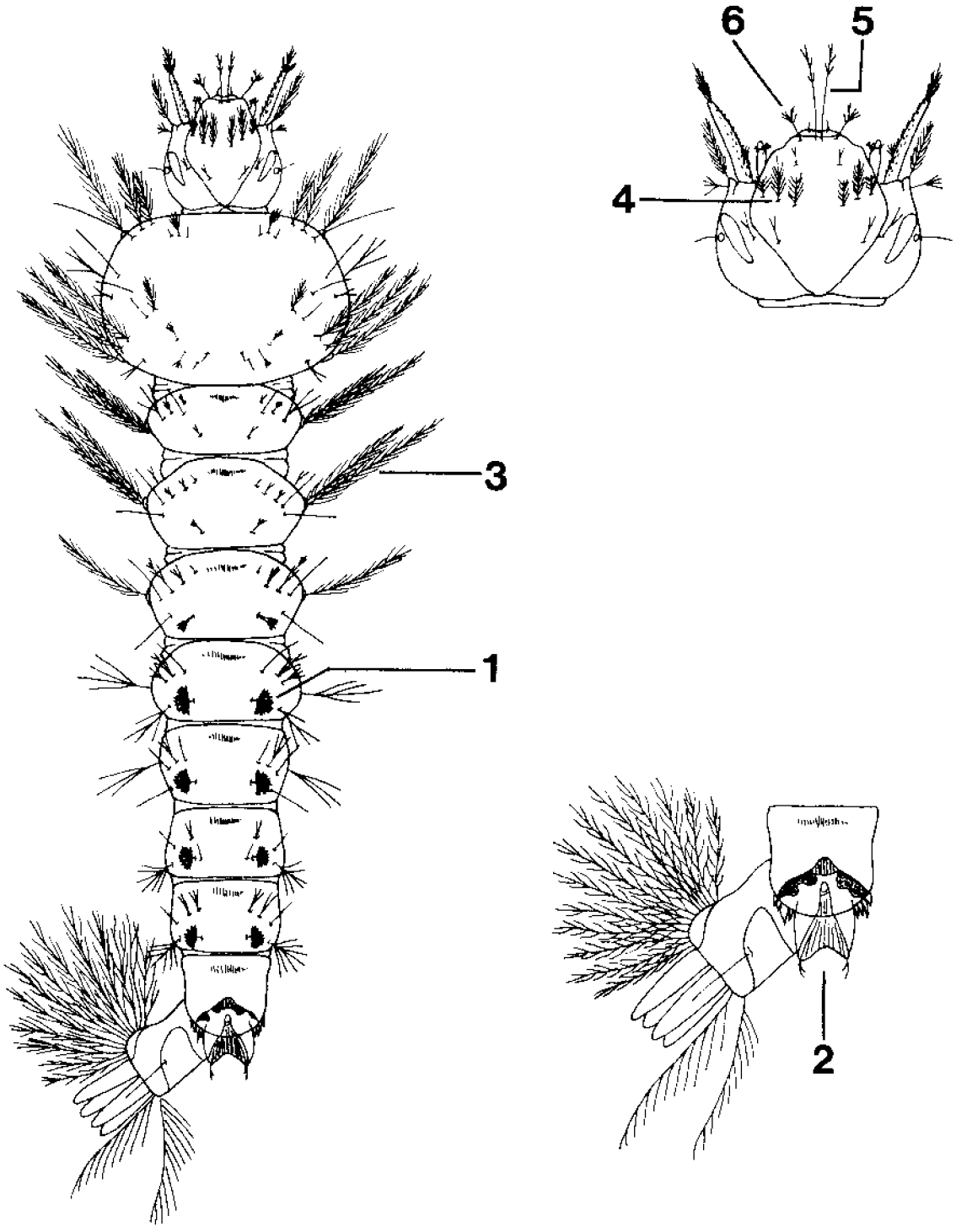
1. Respiratory siphon present
2. Siphon gradually narrowing apically or broadening, not for piercing plant tissue
3. Siphon with pecten teeth
4. Head wider than long
5. Abdominal segment VIII without plate
6. Anal segment with a single sclerotized plate
7. Siphon with but a single pair of hairs ventro-laterally or laterally
8. Anal segment ringed by saddle and ventral brush confined to area posterior to it
9. Either upper or lower head hair single, usually both single
10. Pecten with teeth rather evenly spaced
11. Comb with more than 12 scales in 2-3 rows or patch; each scale thorn-shaped or with subequal spinules
12. Comb scales rounded apically and finged with subequal spinules or apical spine less than twice as long as those on either side
13. Abdominal hair 6 with 2-5 branches
14. Anal gills bud-like, shorter than anal segment



Aedes taeniorhynchus

Anopheles atropos

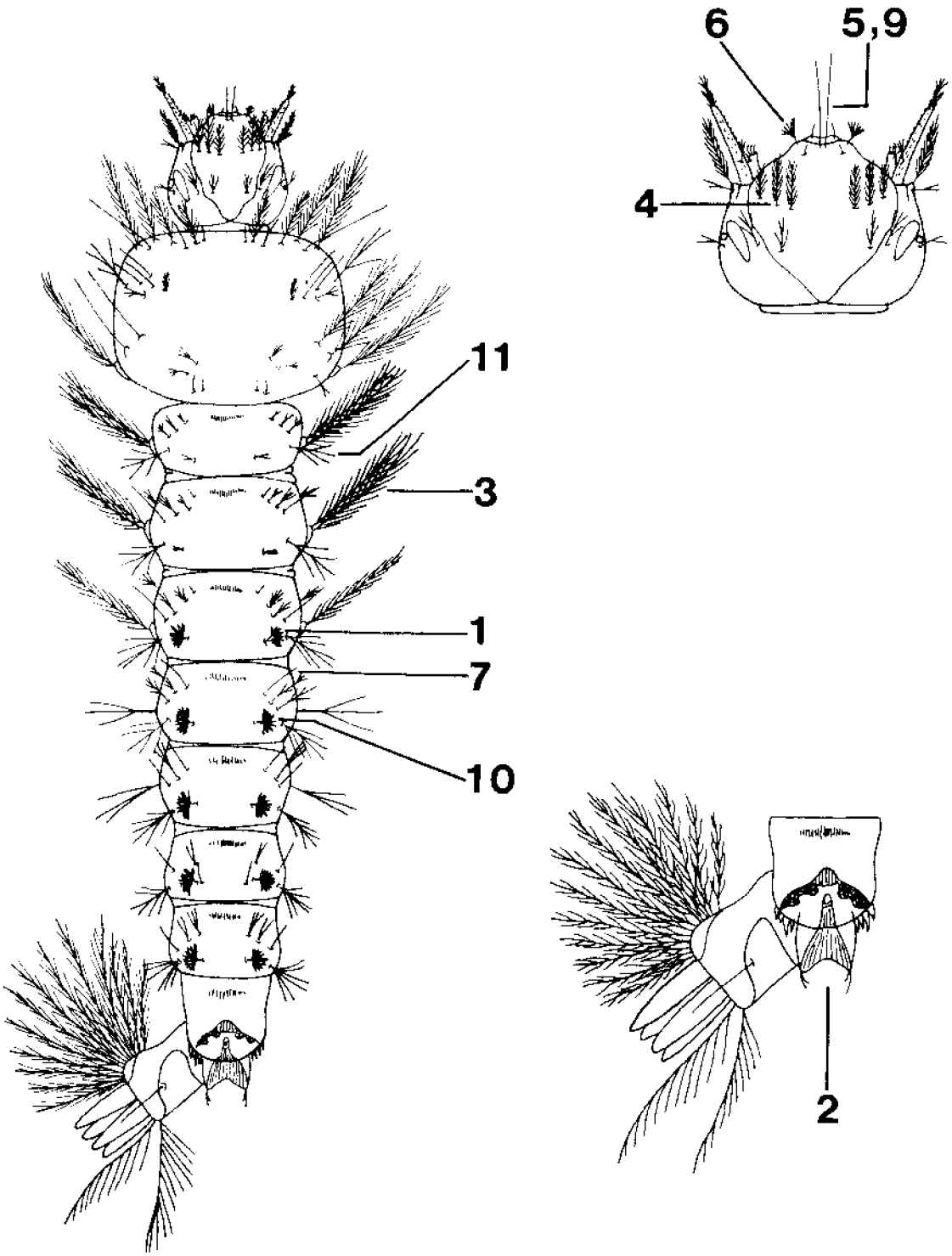
1. Seta 1 on some abdominal segments palmate
2. Respiratory siphon absent
3. Hair 6 only plumose on abdominal segments I-III
4. Head hairs 5-7 large, multi-branched
5. Inner clypeal hairs 2 very close or not separated by much more than the diameter of 1 tubercle
6. Outer clypeal hairs 3 with fewer than 11 branches



Anopheles atropos

Anopheles bradleyi

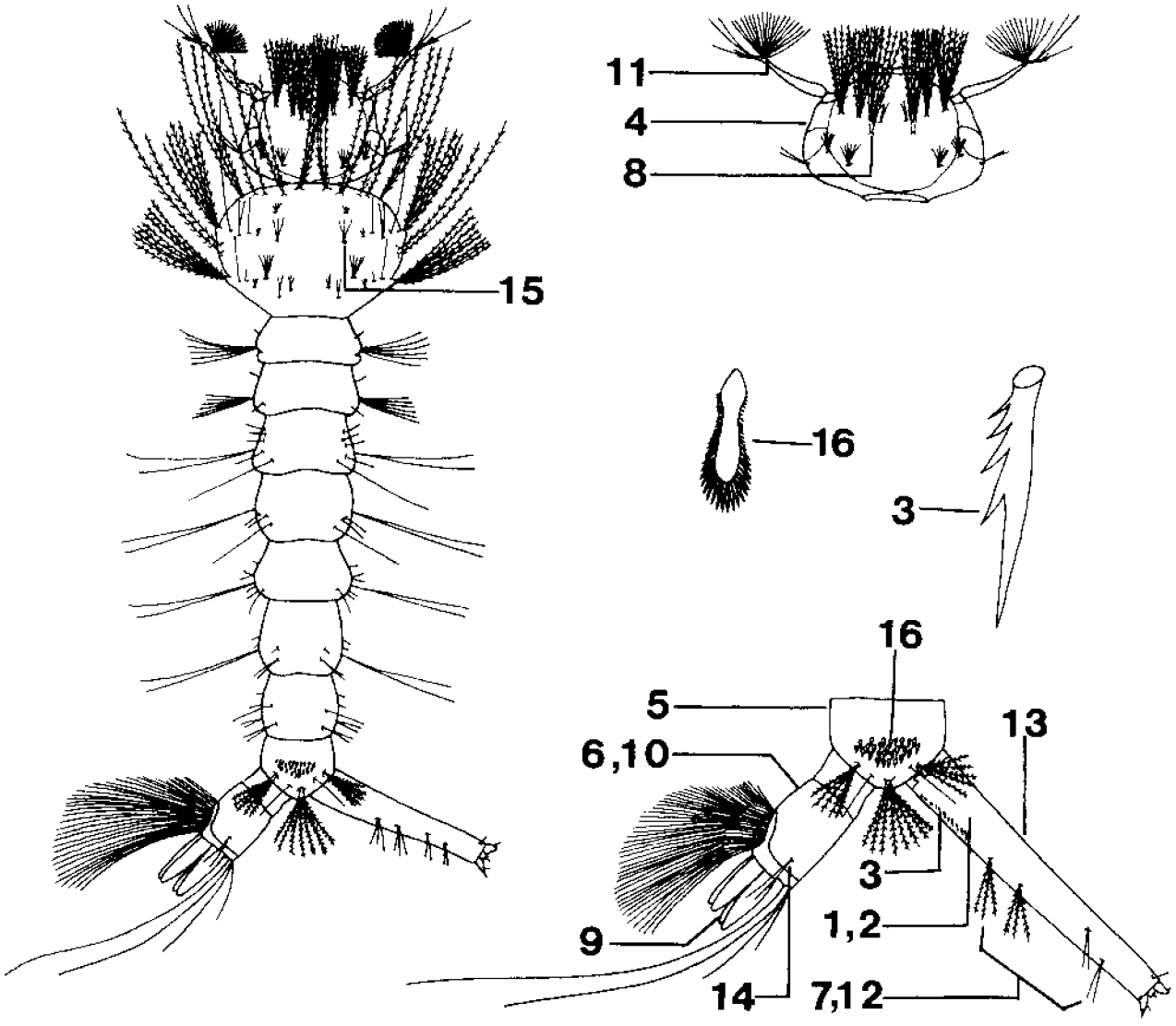
1. Seta 1 on some abdominal segments palmate
2. Respiratory siphon absent
3. Hair 6 only plumose on abdominal segments I-III
4. Head hairs 5-7 large, multi-branched
5. Inner clypeal hairs 2 very close or not separated by much more than the diameter of 1 tubercle
6. Outer clypeal hairs dentritic, densely branched
7. Hair 0 undeveloped or much smaller than 2 or IV-V, the latter usually single or double
8. Prothoracic hair 1 simple or forked toward tip
9. Inner clypeal hair 2 simple or sometimes forked beyond middle
10. Palmate hair 1 on abdominal segments IV-VI about equally developed, those on III and VI not more than 2/3 as large, individual leaflets of palmates on III and VII usually with smooth margins
11. Hair 5 on abdominal segment I usually with 3-5 branches arising from near base



Anopheles bradleyi

Culex salinarius

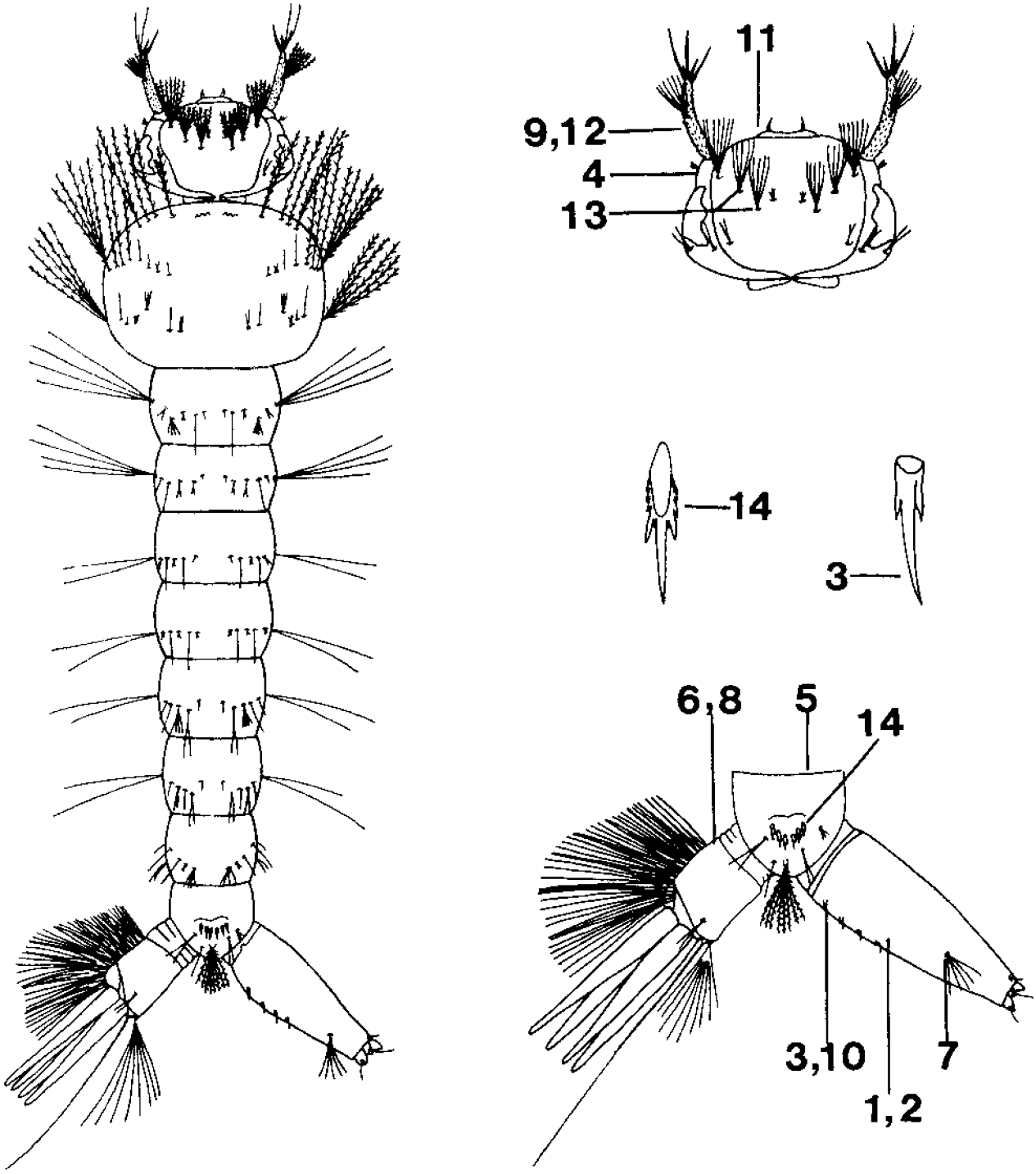
1. Respiratory siphon present
2. Siphon gradually narrowing apically or broadening, not for piercing plant tissue
3. Siphon with pecten teeth
4. Head wider than long
5. Abdominal segment VIII without plate
6. Anal segment with a single sclerotized plate
7. Siphon with 3 or more pairs of hairs ventro-laterally or laterally
8. Head hairs 5 and 6 with 3 or more long branches
9. With 4 anal gills
10. Saddle sclerite completely ringing anal segment
11. Antennal hair 1 attached at constriction in outer third, the part distal to hair more slender
12. Siphon with hairs not in straight line, subapical pair laterally out of line, usually 4 in number
13. Siphonal index 6.0-8.0
14. Hair 1 of anal segment usually double
15. Mesothoracic hair 1 much longer than hair 2
16. Comb of eighth segment with many scales in a patch; individual scale rounded apically and fringed with subequal spinules



Culex salinarius

Psorophora confinnis

1. Respiratory siphon present
2. Siphon gradually narrowing apically or broadening, not for piercing plant tissue
3. Siphon with pecten teeth
4. Head wider than long
5. Abdominal segment VIII without plate
6. Anal segment with a single sclerotized plate
7. Siphon with but a single pair of hairs ventro-laterally or laterally
8. Saddle plate completely rings anal segment and is pierced along mid-ventral line by row of tufts or ventral brush
9. Antennae long, reaching well beyond front of head
10. Pecten teeth few, less than 10, not produced into very long filament
11. Head capsule rounded in front
12. Antennae shorter than head capsule
13. Head hairs 5 and 6 with 4 or more branches
14. Comb of eighth segment with 6 (rarely 5) scales, individual scale thorn shaped



Psorophora confinnis

MOSQUITOES OF NORTH CAROLINA

Species	Breeding Habits	Flight Range	Economic Importance	Disease Transmission
Genus: Aedes				
aegypti	Artificial containers	1-500 ft.	(1) & (4)	Yellow fever - Dengue
atlanticus	Temporary woodland pools	In woods	(2)	
atropalpus	Rock holes in stream beds		(4)	EE Experimentally
canadensis	Temporary woodland pools		(2)	
cinereus	" " "		(4)	
dupreei	Temporary rain pools		(4)	
fulvuspallens	Temporary pools in deep woods	In woods	(4)	
infirmatus	Temporary pools	In woods	(2)	
mitchellae	Temporary woodland pools		(4)	
sollicitans	Salt marshes	5-50 mi.	(1) & (2)	EE Experimentally
sticticus	River bottom flood pools	10 mi.	(2) & (4)	
taeniorhynchus	Salt marshes	5-10 mi.	(1) & (2)	EE Experimentally
thibaulti	Gum tree rot holes		(4)	
tormentor	Temporary woodland pools		(4)	
triseriatus	Tree holes - artificial containers	In woods	(2)	
trivittatus	Floodwater woodland pools		(4)	
vexans	Flood plain pools and rain filled depressions	5-30 mi.	(2)	EE - WE - SLE Fowl pox
Genus: Anopheles				
atropos	Brackish water	1 mi.	(4)	
barberi	Tree holes		(4)	
bradleyi	Brackish water	1 mi.	(4)	
crucians	Acid swamp water	1 mi.	(3)	
georgianus	Seepage pools of acid water		(4)	
perplexens	Limestone springs (Swannanoa, N.C.)		(4)	
punctipennis	Cool weather breeder (spring & fall)	1 mi.	(2)	
quadrimaculatus	Summer species (April - Sept.) neutral water, floatage & cover	1 mi.	(1) & (2)	Malaria
walkeri	Fresh water marshes	1-2 mi.	(4)	
Genus: Culex				
erraticus	Grassy permanent pools		(3)	
nigripalpus	Grassy permanent pools - containers		(4)	SLE
peccator	Pools in swampy areas		(4)	
pilosus	" " "		(4)	
piplens	Polluted water		(4)	Wucheria bancrofti - WE, SLE, & Bird malaria, dog heart worm
quinquefasciatus	Polluted water		(1) & (2)	Wucheria bancrofti - EE, SLE, & Bird malaria, dog heart worm
restuans	Ditches, rain barrels, woodland pools		(2)	
salinarius	Grassy pools - fresh or brackish	8 mi.	(2)	
territans (apicalis)	Permanent fresh water pools	8 mi.	(3)	
Genus: Culiseta				
inornata	Winter breeder - permanent pools		(4)	
melanura	Acid swamp water		(3)	
Genus: Mansonia				
perturbans	Fresh waters with aquatic plants	1-10 mi.	(1) & (4)	
Genus: Orthopodomyia				
alba	Artificial containers, tree holes		(4)	
signifera	" " " "		(4)	
Genus: Psorophora				
ciliata	Temporary pools, predacious		(2)	
confinnis	Temporary pools in fields	1-9 mi.	(1)	
cyanescens	Temporary pools in woodlands		(4)	
discolor	Woodland pools		(4)	
ferox	" "		(2)	
horrida	" "		(4)	
howardii	Temporary pools, predacious		(2)	
varipes	Woodland pools		(2) & (4)	
Genus: Toxorhynchites				
rutilus septentrionalis	Tree hole breeder, predacious		(4)	
Genus: Uranotaenia				
lowii	Grassy lakes, feed on frogs		(4)	
sapphirina	Grassy lakes	8 mi.	(4)	
Genus: Wyeomyia				
haynei (smithii)	Water in leaf of pitcher plant		(4)	

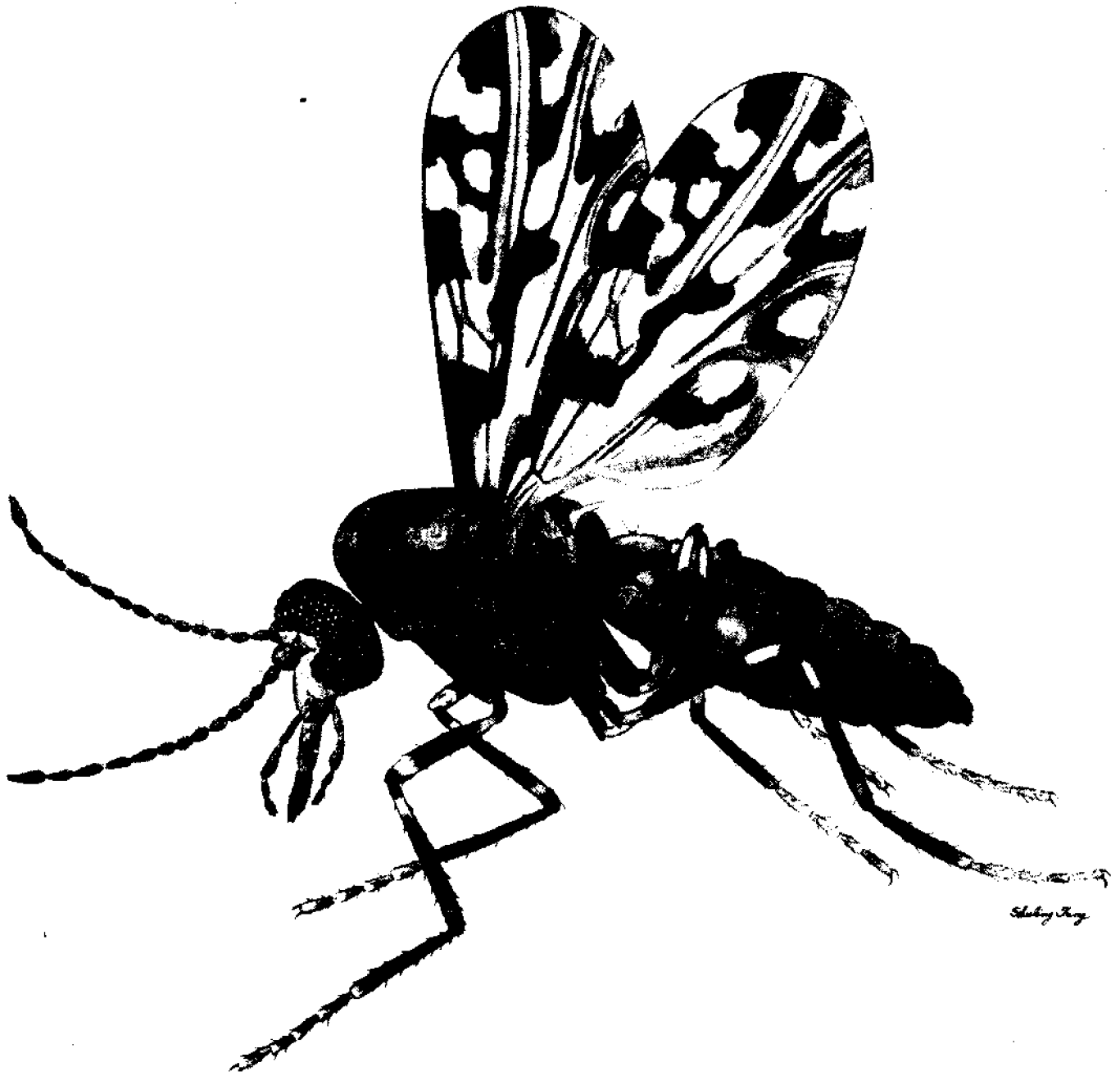
NOTES

(1) Important economic species.
(2) Locally abundant & annoying, principally out-of-doors.
(3) Common species, not very troublesome.
(4) Usually rare or of very restricted distribution.

EE Eastern encephalitis
WE Western encephalitis
SLE St. Louis encephalitis

Compiled by:
D.F. Ashton, Entomologist
N.C. State Board of Health
November 1964

4. *CULICOIDES* SAND FLIES



CULICOIDES SAND FLY (C. furens)

4. *Culicoides* SAND FLIES

Culicoides sand flies are small (12-16 laid end to end equals an inch), blood-sucking flies. They are also commonly known as: "no-see-ums," "punkies," "biting gnats," or "biting midges." Only the females feed on blood. The males feed on plant juices. The annoyance caused by these flies adversely affects tourism and interferes with the recreation of the residents of North Carolina's coastal areas.

There are three major pest species in coastal North Carolina: *C. hollensis*, *C. furens*, and *C. melleus*. *C. stellifer* and *C. niger* are pests to a much lesser degree but are mentioned because from time to time they are abundant in light trap catches.

4.1 LIFE CYCLE

The life cycle of *Culicoides* consists of four life stages. They are as follows (see figure): egg, larva, pupa, and adult. Brief descriptions of the four stages follow.

Egg. It is very difficult to find the egg stage in the field because of its extremely small size (about 100 laid end to end equals an inch). The eggs are laid on the mud or sand near pieces of debris, or in small depressions. When they are first laid, they appear white, but after a few hours they turn dark brown.

Larva. It is white and almost "worm-like" in appearance. The body is divided into two distinct regions. There is a separate head region; the rest of the body is divided into twelve segments. From the last segment protrudes a breathing (brush-like) structure.

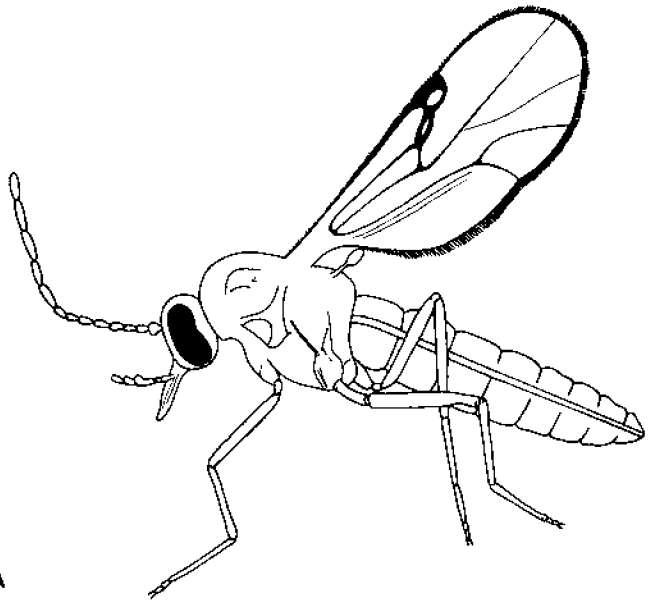
In the process of maturing the larvae pass through four developmental stages (instars). Each succeeding stage becomes a little larger

With proper training all four stages (instars) are large enough to be seen by the naked eye. The size range is from 3 to 12 laid end to end per inch. The larvae of the major coastal species are found either in the mud of salt marshes or in intertidal sand (process to be explained later). They can be seen swimming on the surface of the water with a snake-like motion.

Pupa. The pupa of sand flies is light to dark brown. Its body consists of two distinct regions: cephalothorax and abdomen. Two respiratory horns are on the top of the cephalothorax. Six pupae laid end to end measure an inch. The pupae are found in the same places as the larvae.

Adult. The body of the adult consists of three body regions (see figure): head, thorax, and abdomen. On the head appears a pair of compound eyes, a pair of antennae, and mouthparts. The antennae of the male appear to be hairy. The female mouthparts are adapted for blood-sucking. On the thorax appears a pair of wings, a pair of halteres (small knob-like structures), and three pairs of legs. The wings may be marked with a pattern of light spots against a darker background (e.g., C. furens), or they may be unmarked (e.g., C. melleus). This wing pattern is an extremely important identification character. Another important character is whether or not the legs are banded. The abdomen is the region bearing the reproductive organs. Male terminalia and female spermatheca are important identification characters used by trained taxonomists.

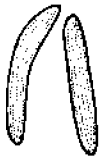
LIFE CYCLE OF CULICOIDES



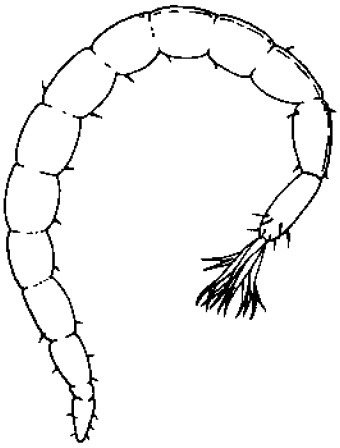
ADULT

PUPA

EGG



LARVA



4.2 BIOLOGY AND IDENTIFICATION

Culicoides hollensis

1. Larval habitats:

   Breeds in salt marshes. Found mainly along ditches and edges of marshes where Spartina alterniflora grows to a height of 2 feet or more.

2. Adults are recognized by the following characters:

   Large greyish species.

   Wings unmarked except for one dark band in costal cell (front edge of wing in half nearest the body).

   Legs are unbanded (uniform in color).

   Female has one large spermatheca.

3. Seasonal adult occurrence:

   This species has two peaks of abundance, one in the spring and another in the fall (see figure).

4. Daily adult occurrence.

   Unlike most Culicoides species, hollensis is most active during the day (see figure).

Culicoides furens

1. Larval habitats:

   Two major habitats have been found in coastal North Carolina, salt marshes and along the banks of tidal creeks protected from violent wave action. In the salt marsh it prefers to breed in Spartina alterniflora less than 2 feet in height. In the tidal creeks it breeds where the Spartina alterniflora and sand occurs; it occurs in very small numbers where only sand is found.

2. Adults are recognized by the following characters:

   Small greyish species.

   Wings marked with many spots.

   Legs are banded (dark with light areas).

   Female has two small spermatheca.

3. Seasonal adult occurrence:

   This species is present from late April to early October (see figure). It has several peaks of abundance. The largest peaks occur in late May, August and September.

4. Daily adult occurrence:

   Active at night. It has peaks of biting activity at sunrise and sunset (see figure).

Culicoides melleus

1. Larval habitats:

   This species breeds in intertidal sand along the banks of tidal creeks protected from violent wave action.

2. Adults are recognized by the following characters:

   Small, distinctly pale yellow species.

   Wings are clearly without spots.

   Legs are unbanded.

   Female has two small spermatheca.

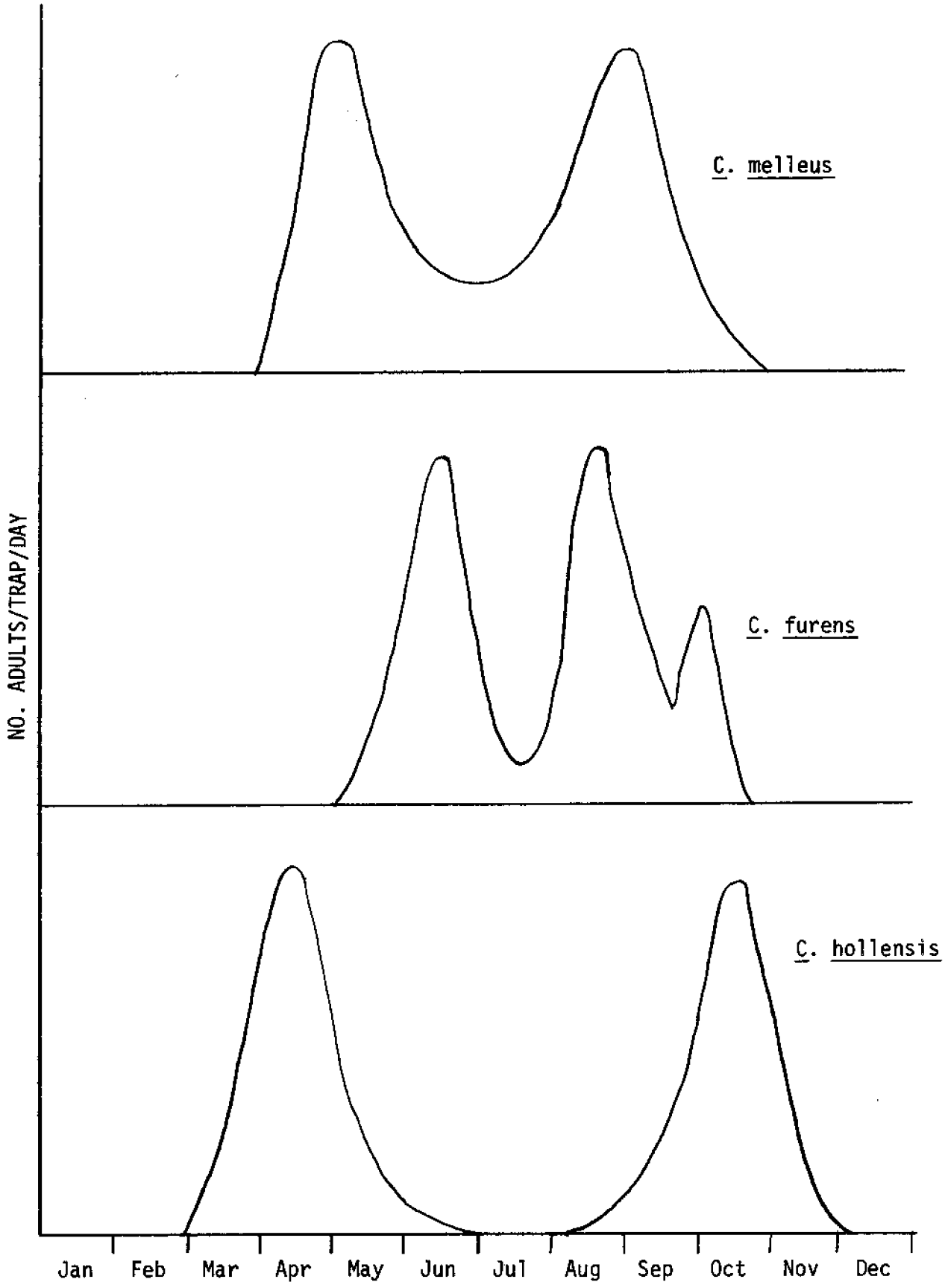
3. Seasonal adult occurrence.

   It appears in early April and lasts until the end of September. It reaches peaks in late April--early May and late August--early September (see figure).

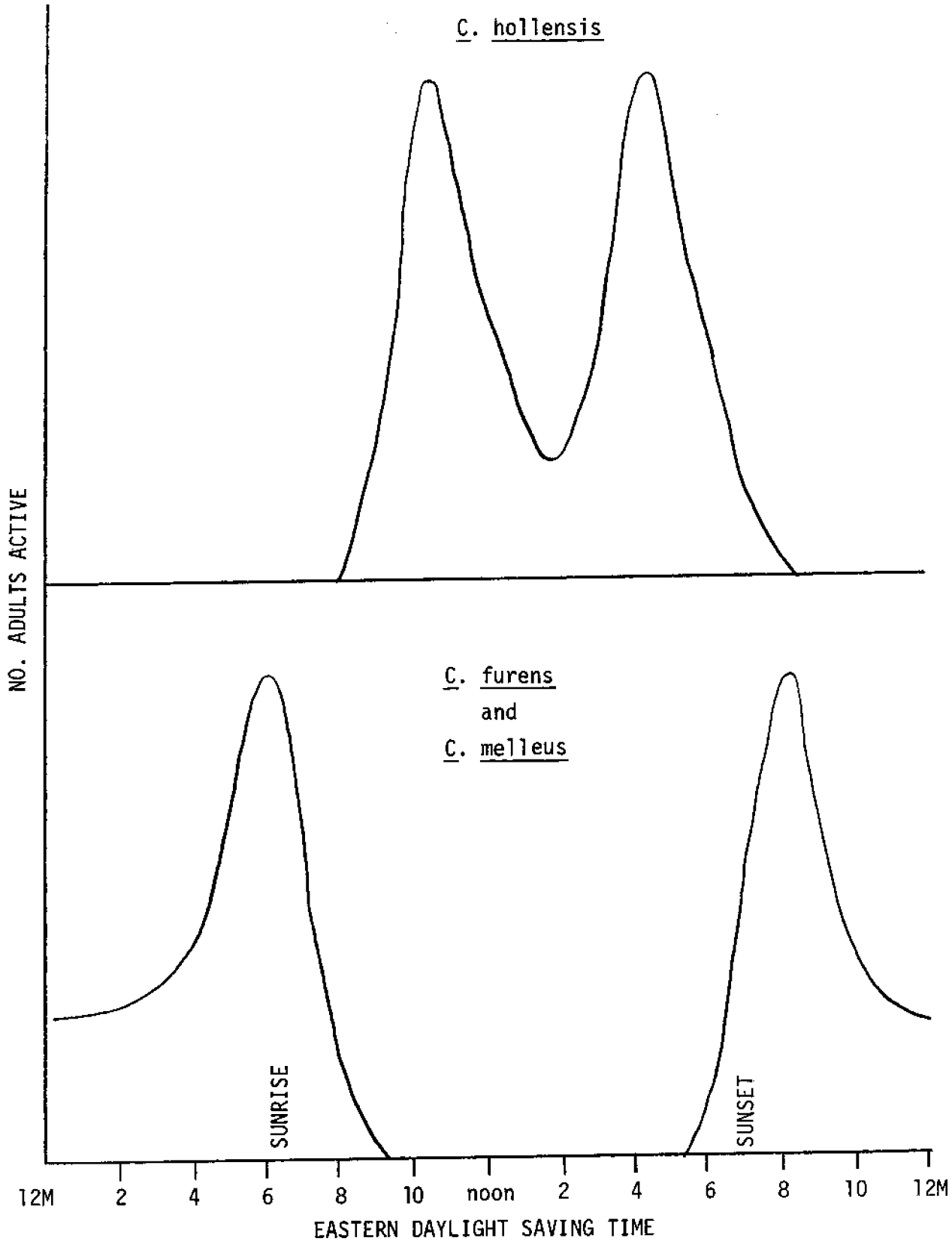
4. Daily adult occurrence:

   Like furens it is active at night; the daily activity curve (see figure) shown for furens also applies to melleus.

C. stellifer and C. niger are minor species which sometimes are found in the light trap collections in large numbers. Their biology is unknown. Their wing patterns are shown.

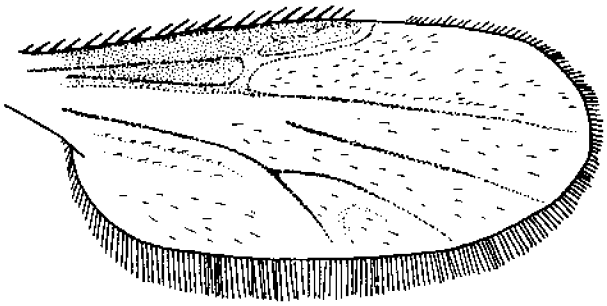


Seasonal Occurrence of Culicoides Sand Flies

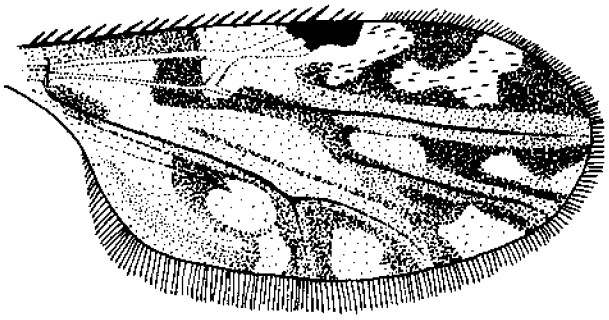


Typical Daily Activity of Culicoides Sand Flies

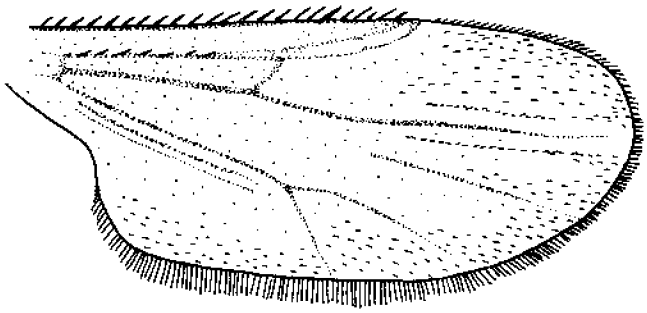
WING PATTERNS OF CULICOIDES



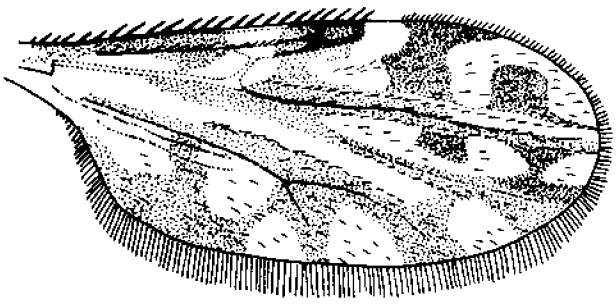
C. hollensis



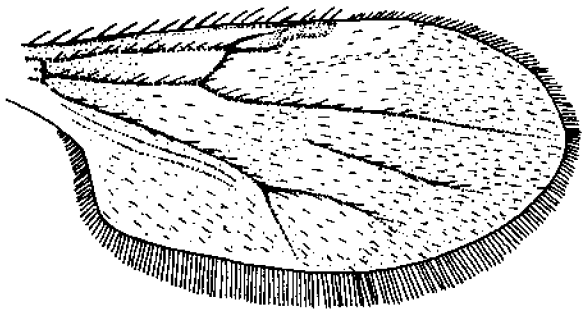
C. furens



C. melleus

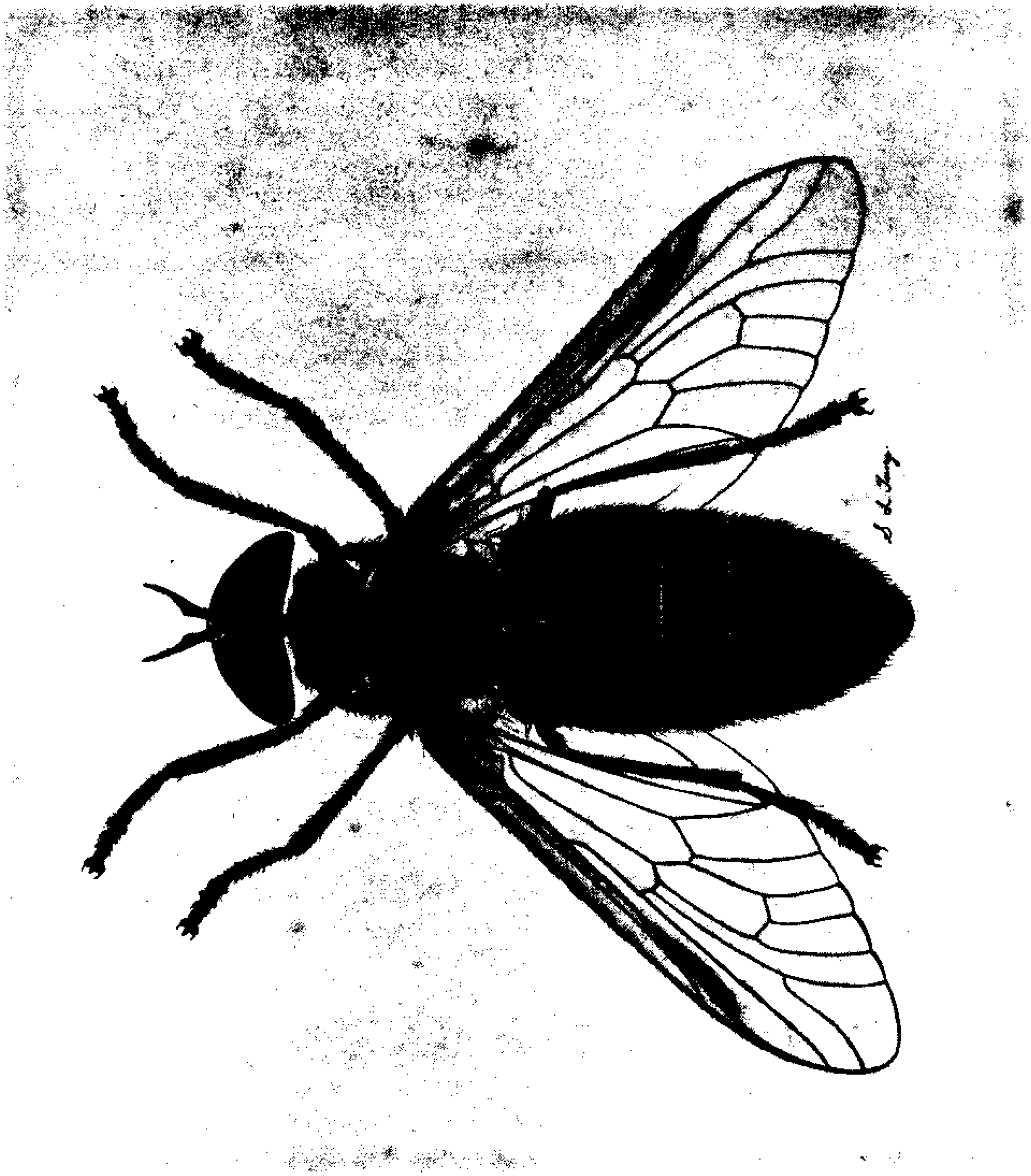


C. stellifer



C. niger

5. TABANID BITING FLIES



GREENHEAD OR HORSE FLY (*Tabanus nigrovittatus*)

DEERFLY (Chrysops atlanticus)

5. TABANID BITING FLIES

There are two types of biting flies in the family Tabanidae. The large ones with fairly clear (may be tinted) wings and very large head are often called horse flies or greenheads. The smaller ones with patterns of black, brown and/or yellow in the wings (and often the body) are commonly called yellow flies or deer flies. The greenheads and the deerflies have differently appearing heads and antennae (see figure). Tabanus is one of the largest genera of greenheads. Chrysops is one of the largest genera of deerflies.

In the coastal area there are more than 40 species of tabanid flies. However, only a dozen of these are common and abundant. All attack man and warm-blooded animals in search for a blood meal. The bar diagrams which follow show the typical periods of occurrence of adults of several species in the central coastal area of North Carolina. The abundance changes drastically during the year and therefore different species become the major pests at different times. The species which are usually of most concern around people are: Tabanus nigrovittatus, T. lineola, C. atlanticus and C. fuliginosis. These and other species are very severe pests of livestock. In local situations different species at various times can be a problem to both man and livestock.

5.1 BIOLOGY AND LIFE CYCLE

Many of these common coastal tabanid flies develop in the soil in the marshes which are regularly flooded by each daily high tide and which have mostly Spartina alterniflora vegetation. This is the principal source of T. nigrovittatus, T. lineola, C. fuliginosus, C. atlanticus and others. Some species are found developing in wet soil, such as in pot

holes, along the margins of ponds and ditches, in the upland areas. For many species we do not know where they develop.

In the coastal areas the major concern is with those developing in the tidal marshes. The general life cycle of these tabanids is as follows. The adults mate and the female lays her eggs in clusters on vegetation (grasses, etc.) in the marsh near the very wet soil. Depending upon the species, the female may or may not need a blood meal before laying some eggs. The eggs quickly hatch and the larvae crawl down the vegetation into the wet soil. The larvae complete their slow development in the marsh soil in about one year. Some may take longer than a year. The larvae grows and molts several times. As shown in the figure which follows, the deerfly (Chrysops) larva is smaller and has a more elongate pointed posterior end than the greenhead (Tabanus) larva. The larva changes into a sluggish pupa in the soil (usually in the very early spring) and in a very few weeks (2-4) the adult fly emerges.

Larvae can be found by washing soil which has been taken from a Spartina alterniflora section of tidal marsh. There are usually only a few larva in a given spot so collecting is difficult, hard work, and involves also a lot of luck. The best time to search for larvae is in the spring (March and April) when there is usually the greatest number of large larvae which are beginning to go into the pupal stage.

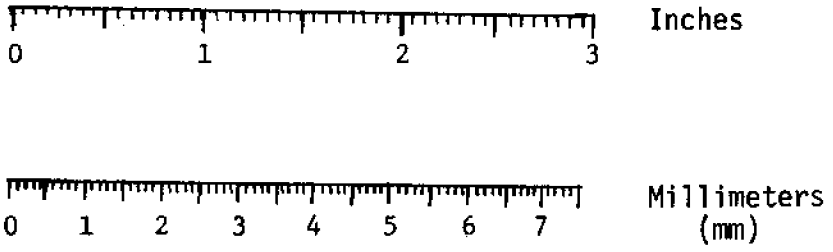
It is more practical to monitor the adult tabanids by using traps and by netting those that come to people or animals.

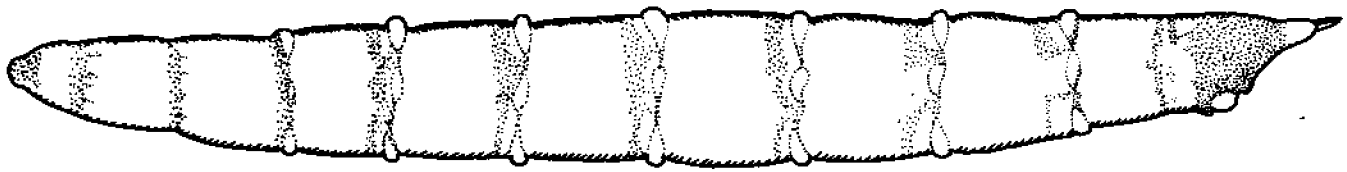
5.2 IDENTIFICATION

Identification of the adults of the most common species of tabanids can be done, with a little practice, with the unaided eye. A hand lens or magnifier would be helpful initially.

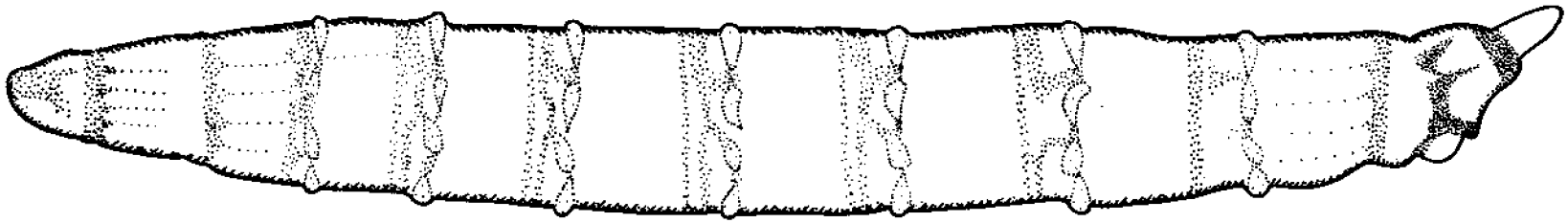
Descriptions of the more common coastal species follows. Caution: this material provides tips for recognizing these common species but there are other less common ones which are similar in appearance. A specialist in tabanid identification should be consulted when positive species identification is critical.

In using these descriptions, the length (from head to rear) of the body of the fly is important and is given first. The scale below will aid in this measurement.

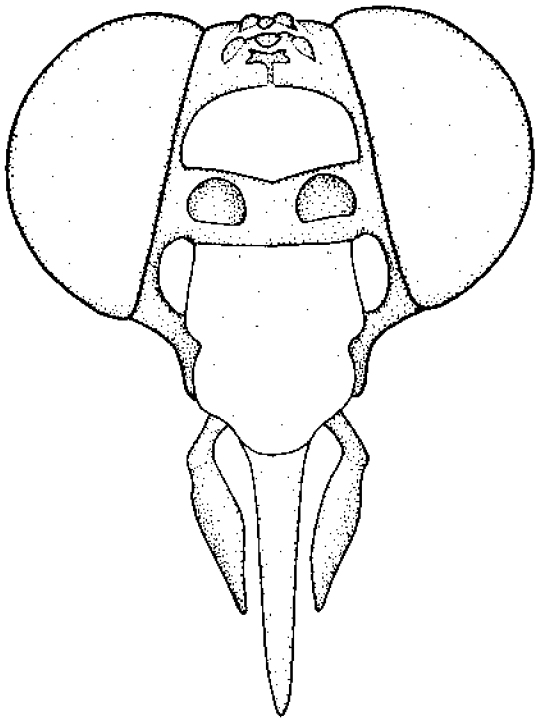




1. Chrysops larva

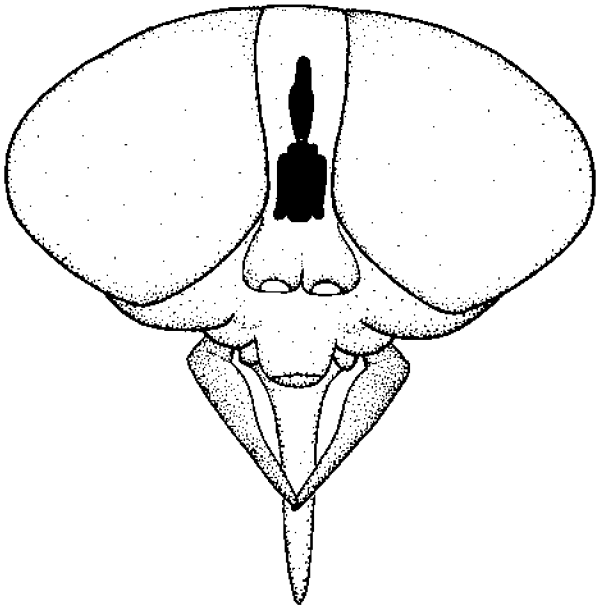


2. Tabanus larva

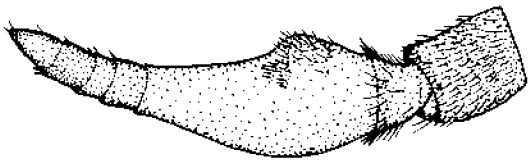


3. Chrysops head

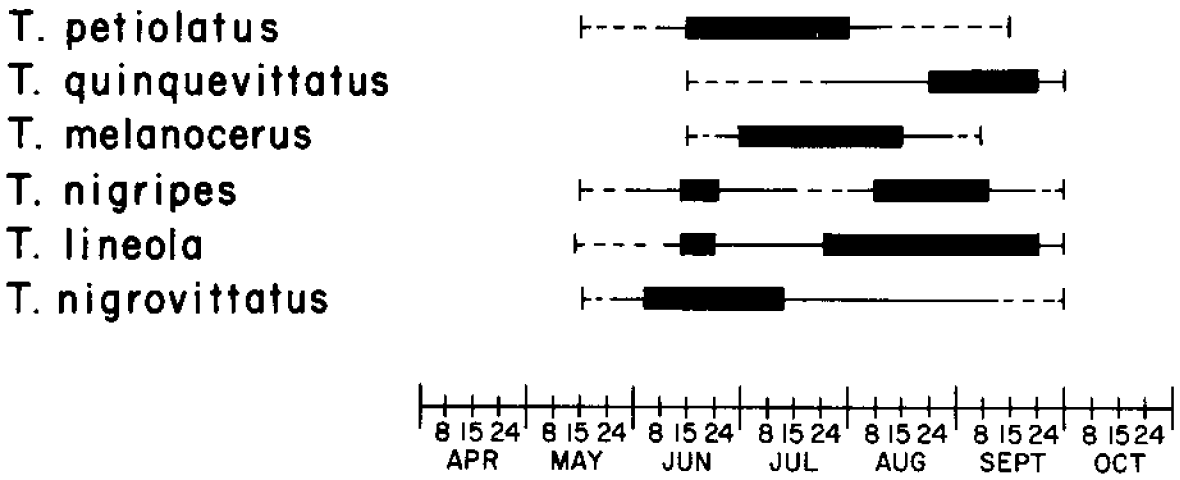
5. Chrysops antennae



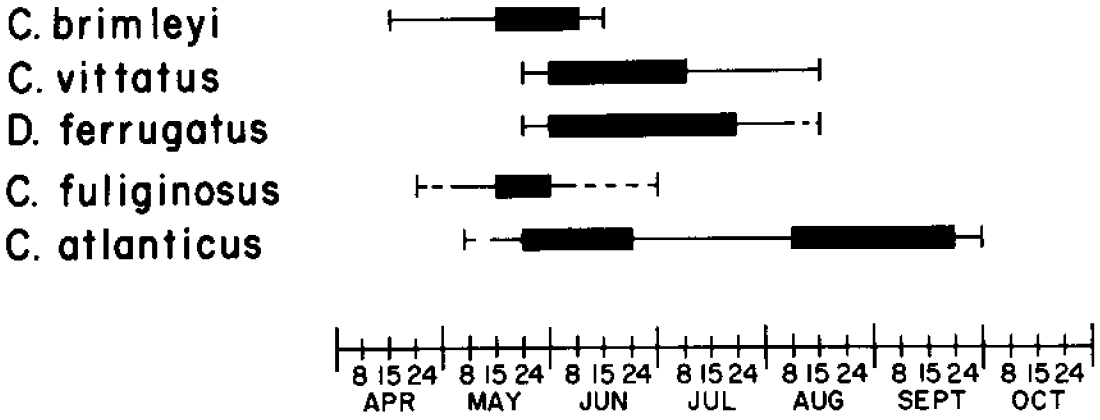
4. Tabanus head



6. Tabanus antennae



Seasonal abundance of major pest species of "greenhead flies" (Tabanidae) in coastal North Carolina. Width of line shows relative abundance.



Seasonal abundance of major pest species of "deerflies" (Chrysopinae) in coastal North Carolina. Width of line shows relative abundance.

Tabanus nigrovittatus

Moderate (12 mm); gray brownish yellow; thorax grayish brown; abdomen with a pale median stripe on a wider dark stripe; segments yellowish laterally (Fig. 1); wings clear with pale yellow costal cell (Fig. 2); palpus creamy white (Fig. 3); pleura grayish white (Fig. 4); frons with sides essentially parallel; eyes bare; fresh specimens; one eye band (Fig. 3).

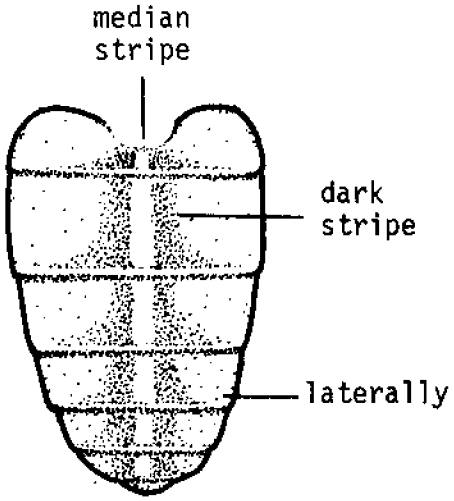


Fig. 1

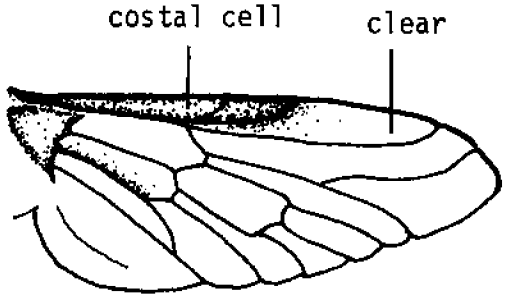


Fig. 2

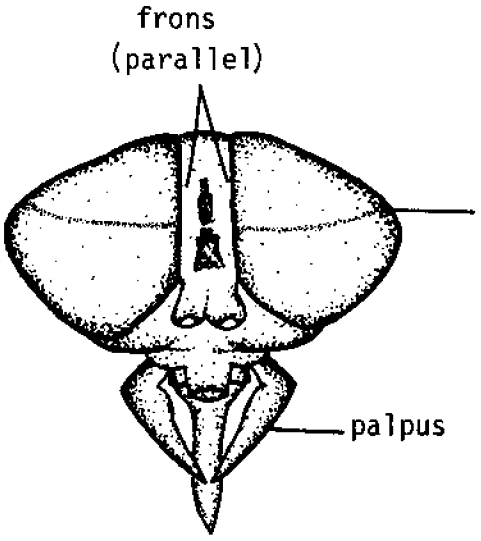


Fig. 3

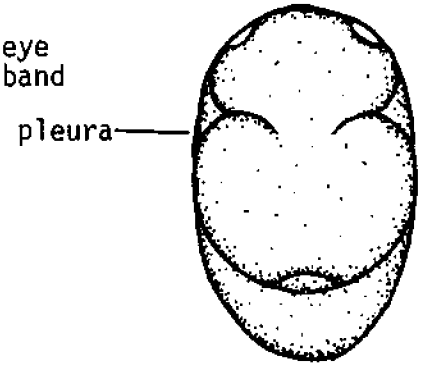


Fig. 4

Tabanus quinquevittatus

Moderate (12 mm); golden brown; thorax golden yellow; abdomen with yellowish golden median stripe bordered with black; lateral margins usually brownish yellow; wings clear with dark yellow costal cell; palpus and pleura distinctly yellowish white; frons with sides essentially parallel; eyes bare; fresh specimens; one eye band (see Figs. 1, 2, 3, & 4).

This species may be confused with T. nigrovittatus, however the dark yellow costal cell, yellowish white palpus and pleura help in separating it from T. nigrovittatus.

Tabanus fuscicostatus

Moderate (12 mm); yellowish brown; thorax gray with yellow cast; abdomen with yellowish golden stripe bordered with black; lateral margins usually brownish orange; wings clear with dark yellowish brown costal cell; palpus white; pleura silky white; frons with sides essentially parallel; eyes bare; fresh specimens, one eye band (see Figs. 1, 2, 3, & 4).

This species is easily separated from T. nigrovittatus and T. quinquevittatus. The most outstanding characteristics are the silky white area on both sides of the thorax and the dark yellowish brown costal cell.

Tabanus lineola

Moderate (13 mm); yellowish brown or nearly black; thorax grayish black; abdomen with yellow median stripe and variable lateral stripes; wings clear, including costal cell; palpus and pleura white; frons narrow and widened above; eyes bare; fresh specimens, three eye bands (Fig. 5).

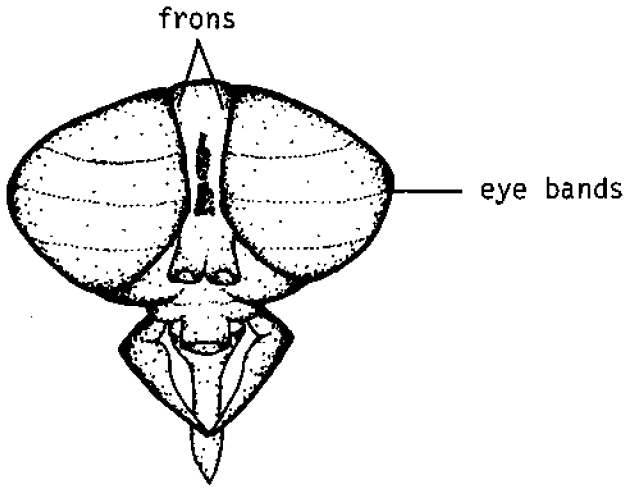


Fig. 5

Tabanus melanocerus

Moderate (16 mm); dark brown to blackish; thorax grayish with whitish lavender overcast; abdomen with median row of pale white triangles; abdominal segments with narrow, sometimes indistinct, pale white bands on the hind margins; triangle on first and second segments rarely meet (Fig. 6); wings clear or sometimes faintly tinted; wing cell R_5 narrows, never closed; costal cell sometimes tinted light yellow (Fig. 7); subcallus grayish white; eyes bare (Fig. 8).

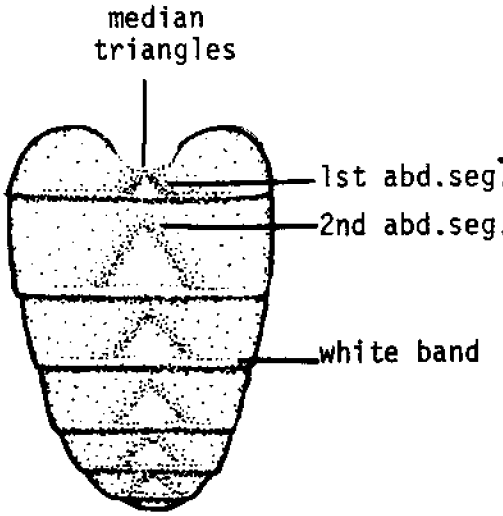


Fig. 6

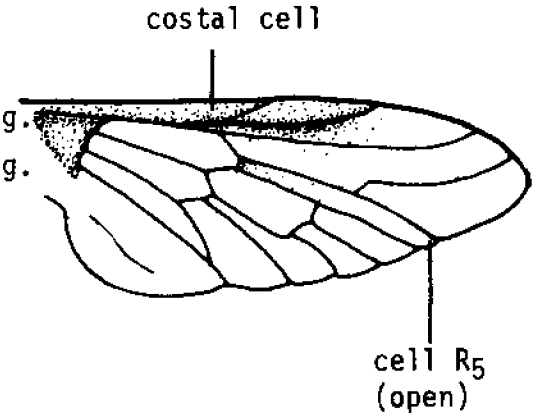


Fig. 7

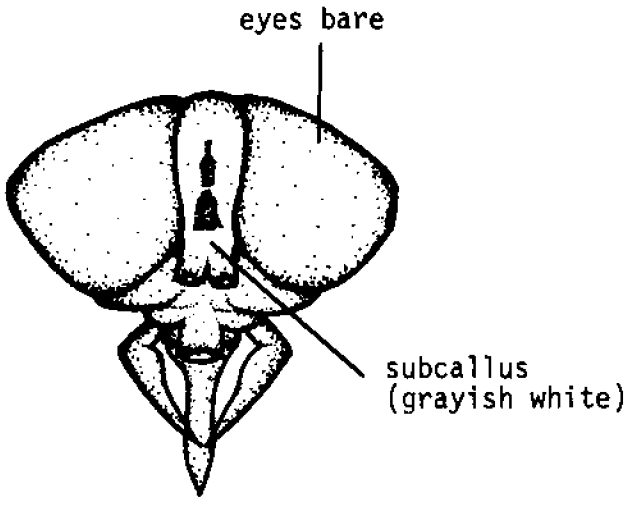


Fig. 8

Tabanus petiolatus

Moderate (16 mm); dark brown to blackish; thorax grayish with white to lavender overcast; abdomen with median row of pale white triangles; abdominal segments with narrow or sometimes indistinct pale white bands on the hind margins; triangle on first and second abdominal segments meet (Fig. 9); wings clear or sometimes faintly tinted; wing cell R_5 closes; costal cell sometimes tinted light yellow (Fig. 10); subcallus grayish white; eyes bare (Fig. 8).

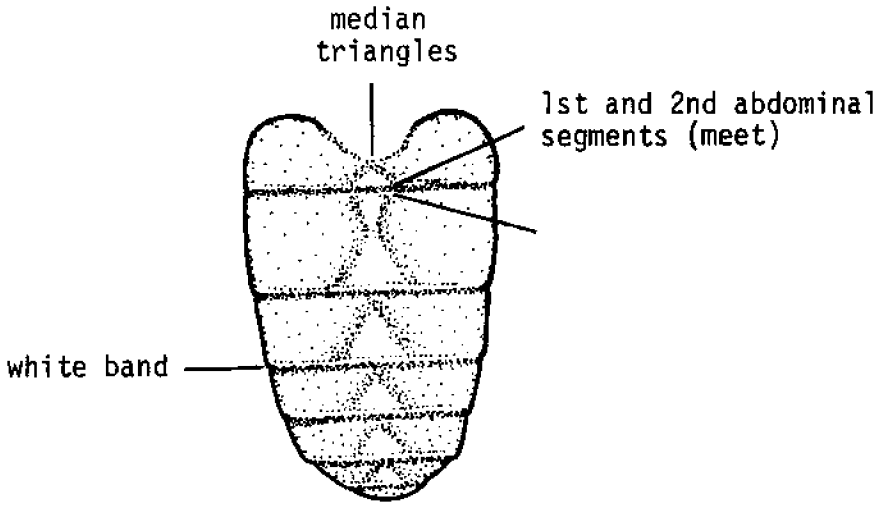


Fig. 9

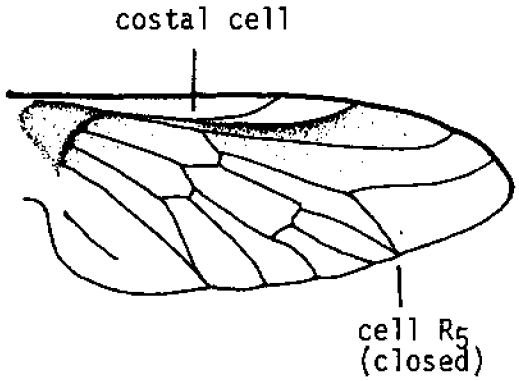


Fig. 10

Tabanus nigripes

Small to moderate (12 mm); blackish gray, thorax blackish gray with lavender cast; abdomen with median row of pale white triangles, and segments with wide pale white bands on hind margins (Fig. 11); wings clear or sometimes faintly tinted with faintly yellow tinted costal cell (Fig. 7); subcallus is black; eyes bare (Fig. 12).

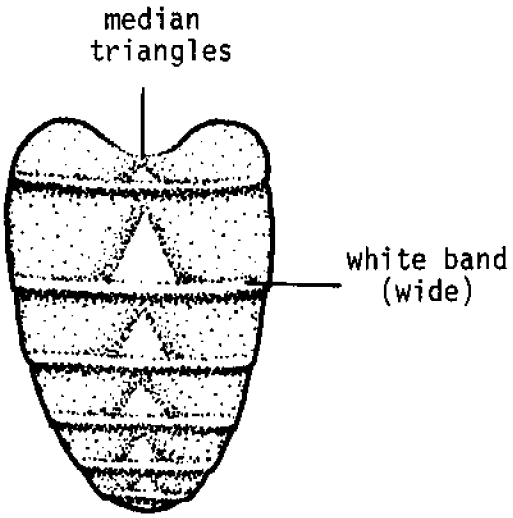


Fig. 11

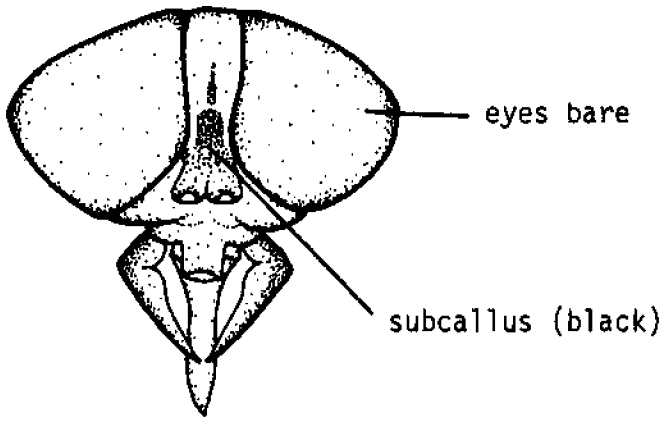


Fig. 12

Tabanus trimaculatus

Moderate (17 mm); blackish gray; thorax light gray with a lavender cast; abdomen brownish black to black with median white triangles on third, fourth and fifth segments (Fig. 13); wings tinted, with dark yellow brown costal cell and dark spots; eyes bare.

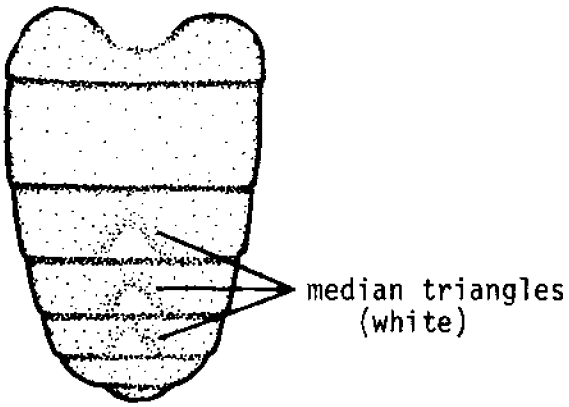


Fig. 13

Tabanus americanus

Large (27 mm); thorax reddish brown with whitish lavender cast; abdomen reddish brown or nearly black, with pale white bands on hind margins of segments; wings clear; small patch white hairs on thorax at wing base; dark reddish brown costal cell (Fig. 14); eyes bare.

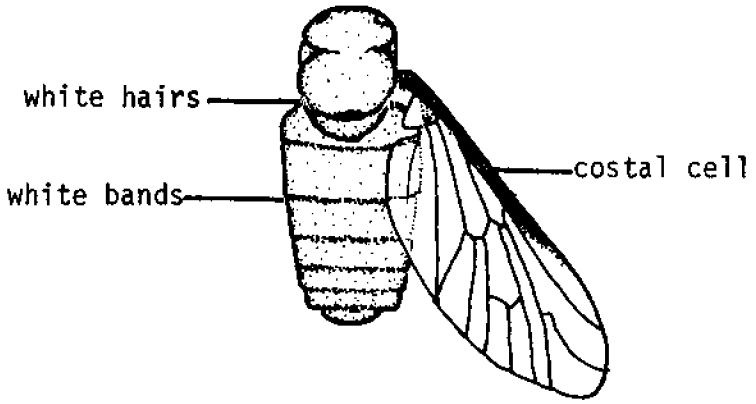


Fig. 14

Tabanus atratus

Large (25 mm); thorax, abdomen and wings black; eyes bare.

Tabanus gladiator

Large (25 mm); reddish brown; thorax reddish brown with whitish lavender cast; abdomen dark reddish brown, sometimes with median row indistinct black spots (Fig. 15); wing somewhat tinted, with dark spots and dark brownish yellow costal cell (Fig. 16); eyes bare.

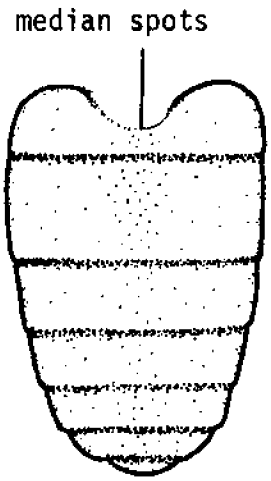


Fig. 15

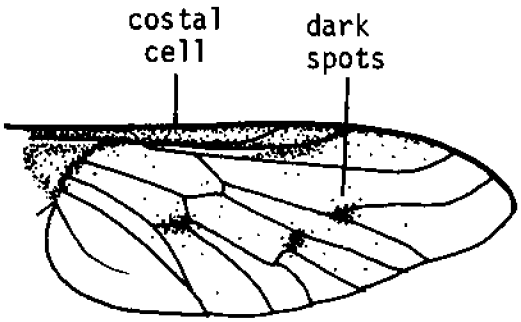


Fig. 16

Tabanus sulcifrons

Fairly large (22 mm); reddish brown; thorax reddish brown with whitish lavender cast; abdomen dark reddish brown with median row pale white triangles (Fig. 17); wing tinted, with dark spots and dark brownish yellow costal cell (Fig. 18); eyes bare.

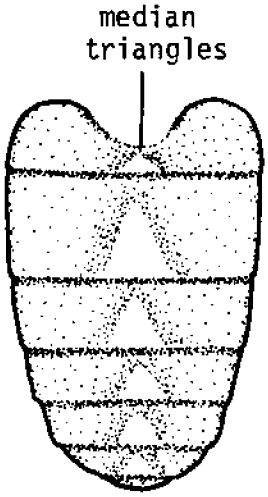


Fig. 17

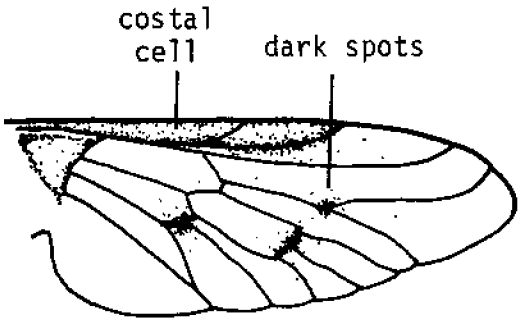


Fig. 18

Tabanus pumilus

Small (10 mm); dark brown to grayish black; abdomen with very faint median row of triangles and light gray to brown sublateral spots (Fig. 19); wings clear; median callus widened (Fig. 20).

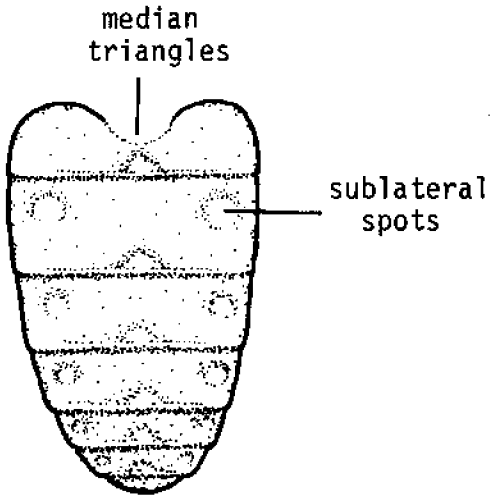


Fig. 19

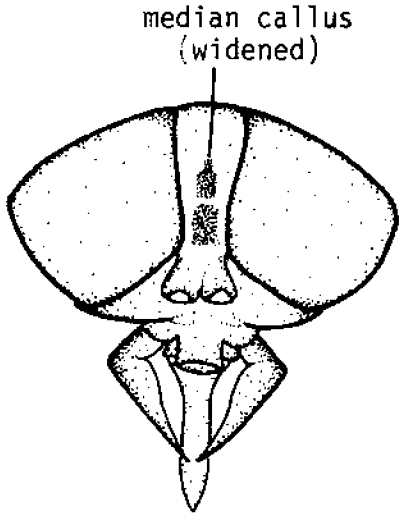


Fig. 20

Tabanus sparus milleri

Small (10 mm); dark brown to grayish black; abdomen with very faint median row of triangles and light gray to brown sublateral spots (Fig. 19); wings clear; median callus narrow (Fig. 21).

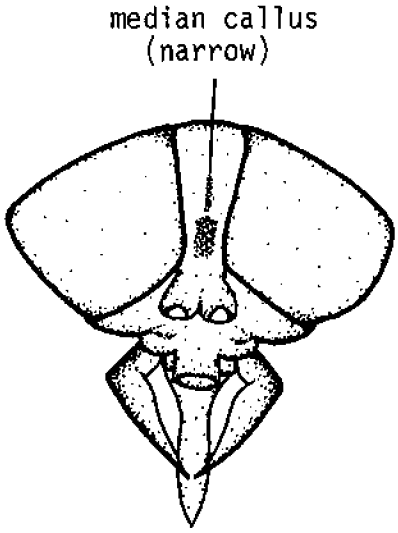


Fig. 21

Chlorotabanus crepuscularis

Moderate (14 mm); thorax and abdomen uniformly greenish yellow; wings clear with inconspicious dark spots (Fig. 22); body compact; eyes reddish brown; eyes bare.

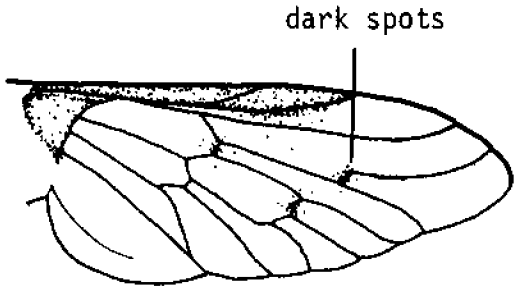


Fig. 22

Hybomitra daeckei

Moderate (14 mm); brownish; thorax dark brown to black and distinctly hairy (Fig. 1); abdomen broadly orange brown laterally with a faint white stripe on a dark median stripe (Fig. 2); wings with a uniform yellow tint (Fig. 3); eyes hairy; fresh specimens, four eye bands (Fig. 4).

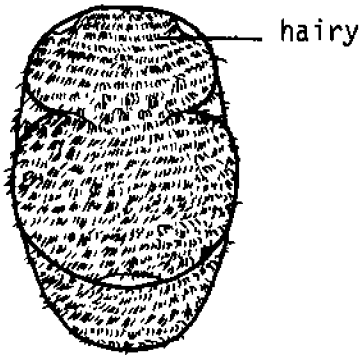


Fig. 1

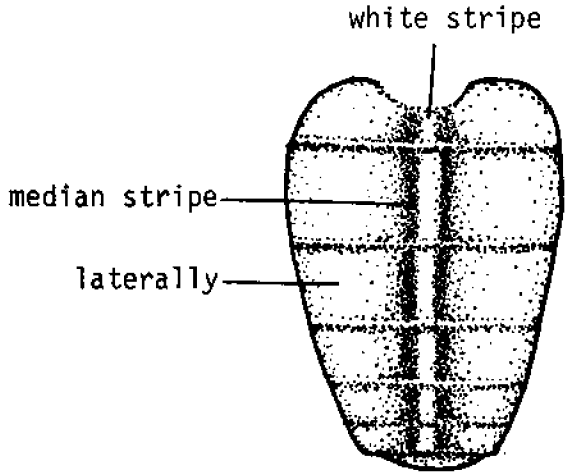


Fig. 2

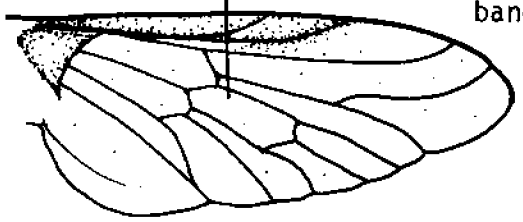


Fig. 3

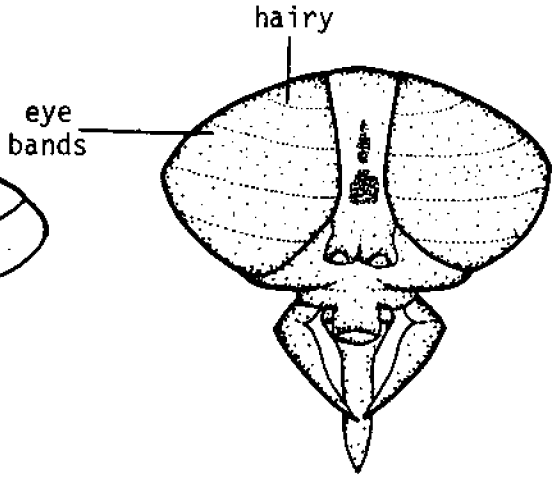


Fig. 4

Hybomitra hinei

Small to moderate (12 mm); thorax and abdomen distinctly shiny black (Figs. 5 & 6); abdomen with yellowish orange laterally (Fig. 6); wings tinted dark yellow brown; eyes hairy; fresh specimens, four eye bands (Fig. 4).

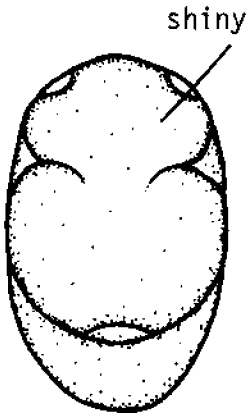


Fig. 5

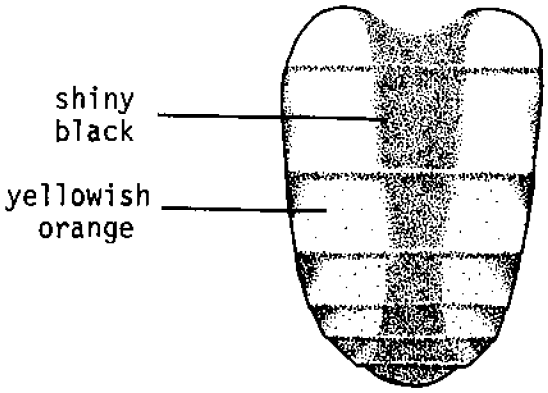


Fig. 6

Hybomitra lasiophthalma

Moderate (14 mm); brownish black; thorax dark brown to black and distinctly hairy (Fig. 1); abdomen yellowish brown laterally with dark median sometimes forming triangles (Fig. 7); wings are clear or faintly tinted, with conspicious dark spots and a yellow costal cell (Fig. 8); eyes hairy; fresh specimens, four eye bands (Fig. 4).

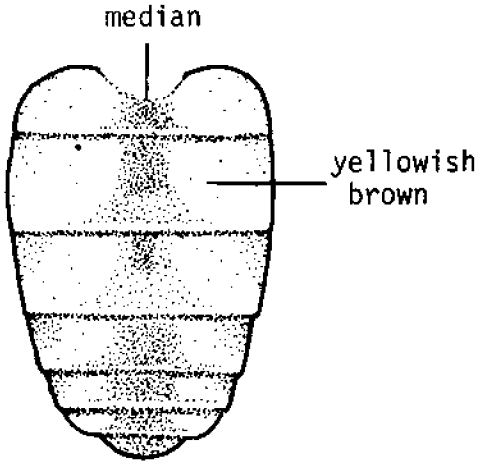


Fig. 7

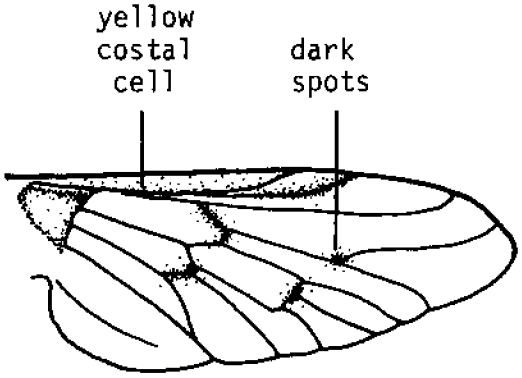


Fig. 8

Chrysops atlanticus

Rather large (9 mm); dull yellow and brown; thorax greenish yellow with three dark brown to black stripes (Fig. 1); black pattern on abdomen usually form light yellow triangles (Fig. 2); dark pattern never form stripes; wing membrane tinted (smoky gray brown) with pattern showing as darker area; both basal cells partly tinted (Fig. 3).

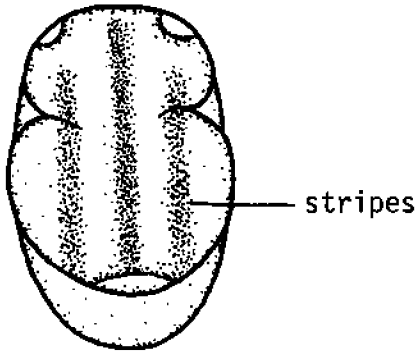


Fig. 1

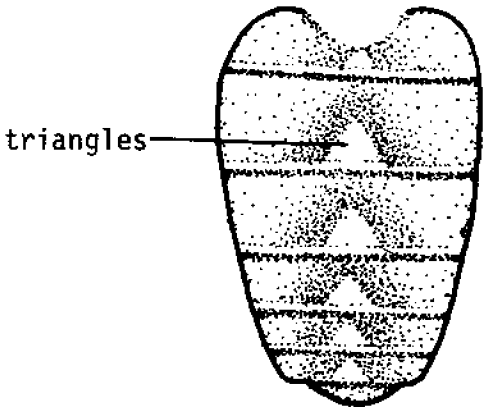


Fig. 2

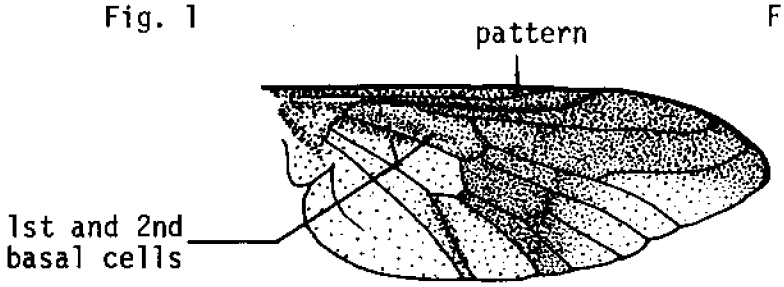


Fig. 3

Chrysops brimleyi

Moderate (8 mm); dark grayish black; abdomen with traces of a grayish pattern; first basal cell tinted; second clear; narrow apical spot; small black spot at fork (Fig. 4).

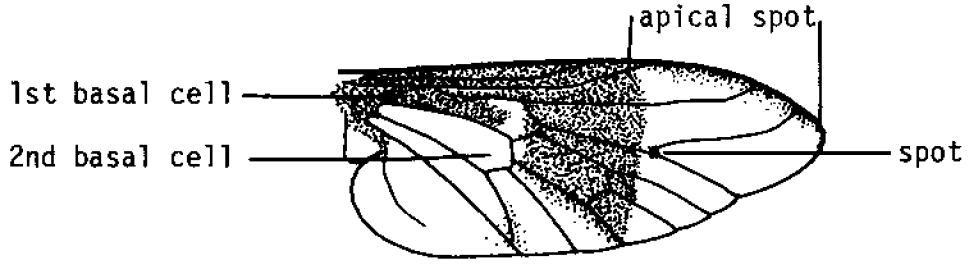


Fig. 4

Chrysops flavidus

Rather large (9 mm); yellow and brown; thorax yellow with three dark brown stripes (Fig. 5); dark brown pattern on abdomen usually form light yellow triangles (Fig. 6); brown pattern never form stripes; wing membrane pattern showing as darker area; both basal cells somewhat tinted at base; broad apical spot (Fig. 7).

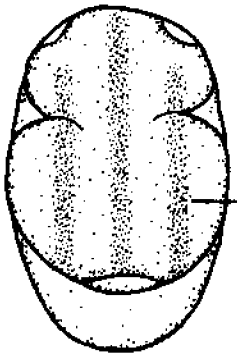


Fig. 5

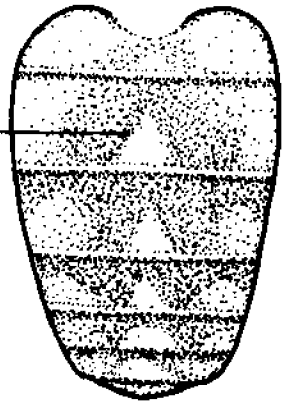


Fig. 6

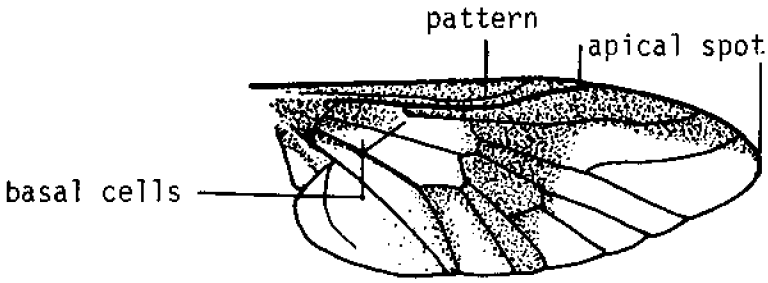


Fig. 7

Chrysops fuliginosus

Rather small (7 mm); dark grayish black; sometimes with traces of pale gray pattern on abdomen, wing membrane tinted; with usual dark pattern heavier tinted; first basal cell tinted, second basal cell somewhat tinted; broad apical spot, nearly separated from cross band (Fig. 8).

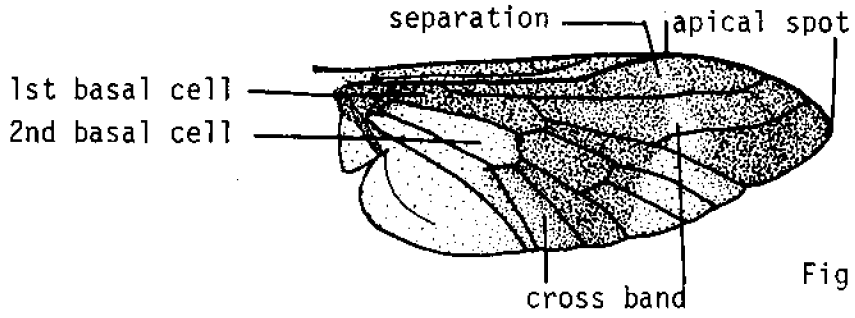


Fig. 8

Chrysops vittatus

Moderate (8 mm); yellow and black; thorax yellow with three dark brown to black stripes (Fig. 9); four black stripes on abdomen (Fig. 10); first basal cell tinted; second basal cell base partly tinted; apical spot broad (Fig. 11).

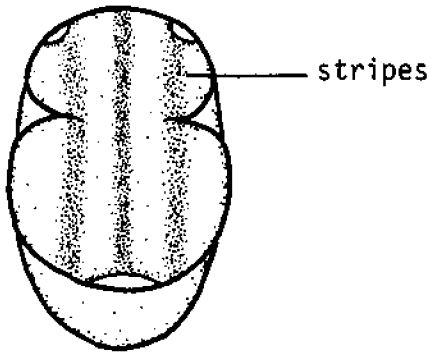


Fig. 9

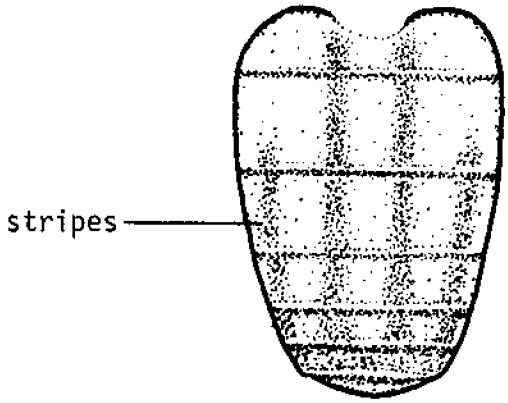


Fig. 10

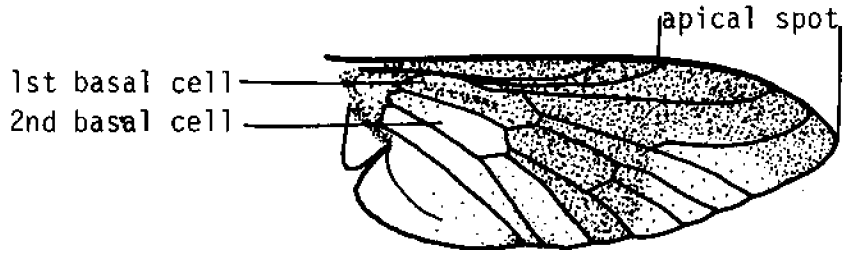


Fig. 11

Diachlorus ferrugatus

It is a different subfamily but resembles Chrysops in general appearance. Rather large (10 mm); bright yellow-gold and brown; thorax is golden brown without stripes; dark brown pattern on both sides of abdomen; broad gold abdominal stripe (Fig. 12); wing membrane slightly tinted with dark brown apical spot (Fig. 13).

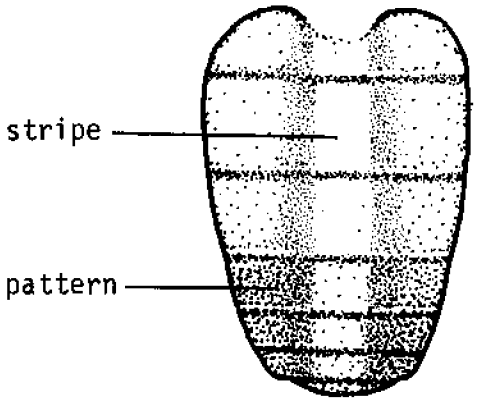


Fig. 12

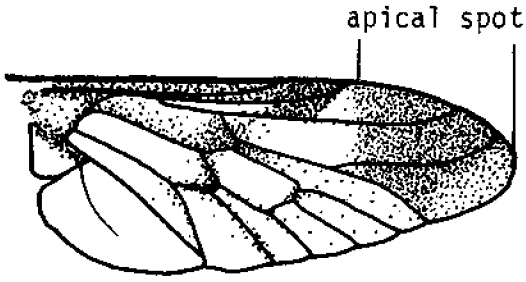


Fig. 13

6. SAMPLING AND MONITORING

6. SAMPLING AND MONITORING

6.1 GENERAL METHODS

It is essential to have some planned, orderly, uniform procedures for estimating the numbers of mosquitoes and biting flies throughout the entire year. This is necessary to answer the questions: What is the problem? When is the problem? Where is the problem? This is necessary to determine whether or not control measures should be initiated. It is necessary to evaluate the effectiveness of any control measures after they are used.

There are great variations between localities and between years in the numbers and species of insects. Continuous sampling and monitoring of the populations year after year is essential to justifying what has been done or what is proposed to be done.

Mosquitoes and Sand Flies

Common methods for sampling mosquitoes and sand flies are as follows:

Light traps: The light trap (Figure 1) is a basic tool. It is usually operated in AC 110 V current but battery models can be used for short periods. The light trap has a light bulb at the top and a fan which draws the insects downward into a collecting jar on the bottom. To kill the insects in the collecting jar, pieces of "No-Pest" strip (DDVP) are added. A paper cup (with small holes in the sides and bottom) is suspended from the lip of the jar to keep the insects away from any moisture that collects inside the jar. To have good specimens, the collection should be removed each day.

The light trap gives adequate samples of many common species of mosquitoes and Culicoides sand flies. Some species do not come to the

the light trap, however. Moon light will decrease the size of the collections. The numbers and species of insects collected in the light trap is one measure of the population but others must be used.

Landing rates: Collections of mosquitoes and sand flies from a person is an excellent sampling method. This should be done routinely at preselected sites. Usually a 10-minute period is used. An aspirator is usually used (Figure 2). This is difficult in the semidark or darkness and then a flashlight must be used for brief periods. Samples should be taken at various times from before sunset to after sunrise. The species will differ in the activity at different time periods. The times of collection have to be standard for you to compare between days, weeks, months, or years. Besides aspirating some specimens for identification, you should estimate the total number of mosquitoes or sand flies coming to you in 10 minutes. It is also possible to net the mosquitoes if you do it carefully enough so as not to destroy the specimens. Rotate the net slowly around your body, particularly around the legs and ankles.

Larval sampling: Larvae of mosquitoes are routinely sampled by dipping (Figure 3). Further detail is given in the mosquito section ("Evaluation of Mosquito Production from Coastal Salt Marshes").

Larvae of Culicoides sand flies are in the marsh soil and cannot be sampled by dipping. They are sampled by emergence traps or by floating them out of the mud. Further details are given in the section on sand flies.

The field worker should be equipped with a convenient bag to carry notebook, aspirator, net, dipper, forceps, killing jars, etc. as shown in Figure 4.

Greenheads and Deerflies

Collecting adult tabanid flies requires different techniques than those used for mosquitoes and *Culicoides* sand flies. A reliable trap for deerflies is not known. Therefore, deerflies must be sampled by swinging a net rapidly over your head while walking slowly (Figure 5). A standard site and distance (or time) should be used. Usually the best collections are made in the last half of the afternoon.

Greenheads (horseflies) come readily to certain traps. The box trap (Figure 6) collects large numbers of *Tabanus nigrovittatus* which is a common coastal pest. The trap is poor for most other species.

The canopy trap (Figures 7 and 8) collects a greater variety of species of greenheads than does the box trap. There are several designs of canopy traps. The one illustrated is the "North Carolina Rigid Canopy Trap." It was designed and has been tested for use in coastal salt marshes where winds are often strong. As shown in Figure 7 (one side of screen has been removed for the picture), a beach ball painted black is hung inside the trap. This improves the collecting but the trap may be used without the ball.

These traps (box and canopy) should be placed at the edge of the marsh in a position where the trap is fully visible to the insects as they leave the marsh. Where practical, some traps should be in the marsh in front of the upland border of shrubs.

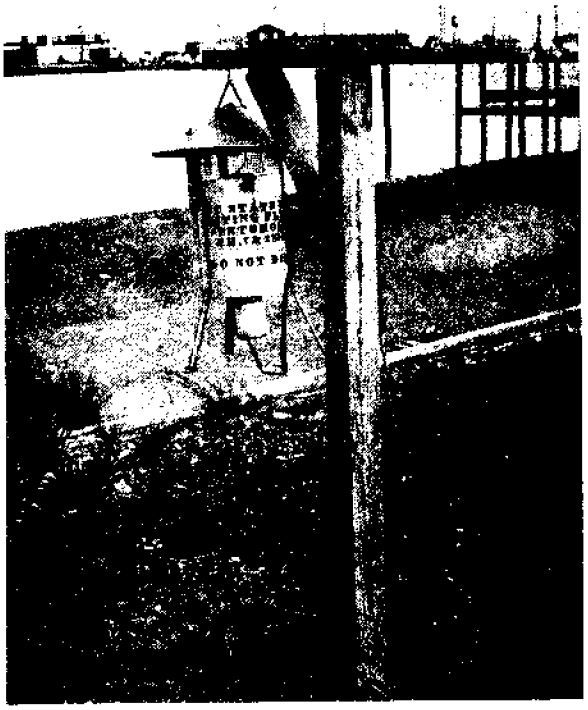


Figure 1

Figure 2

Figure 3

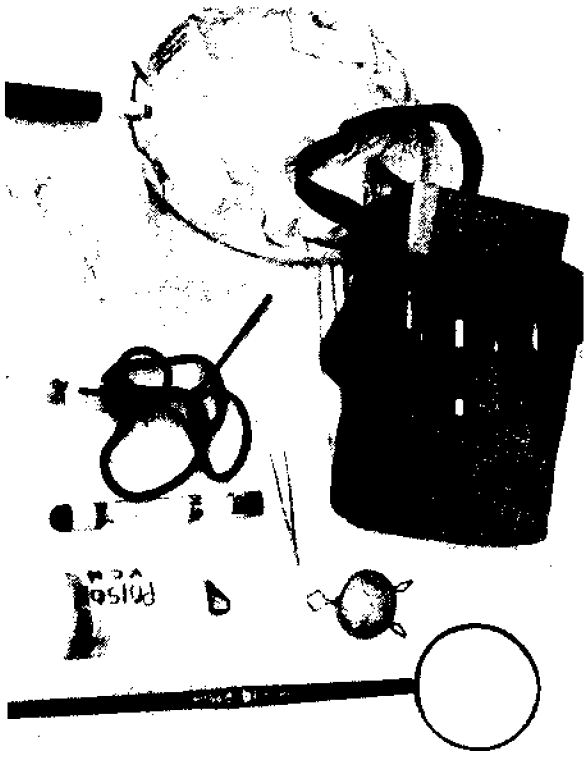


Figure 4

Figure 5

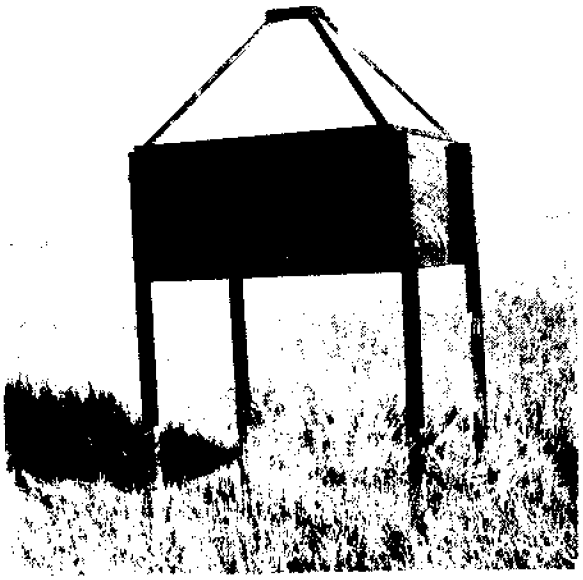


Figure 6

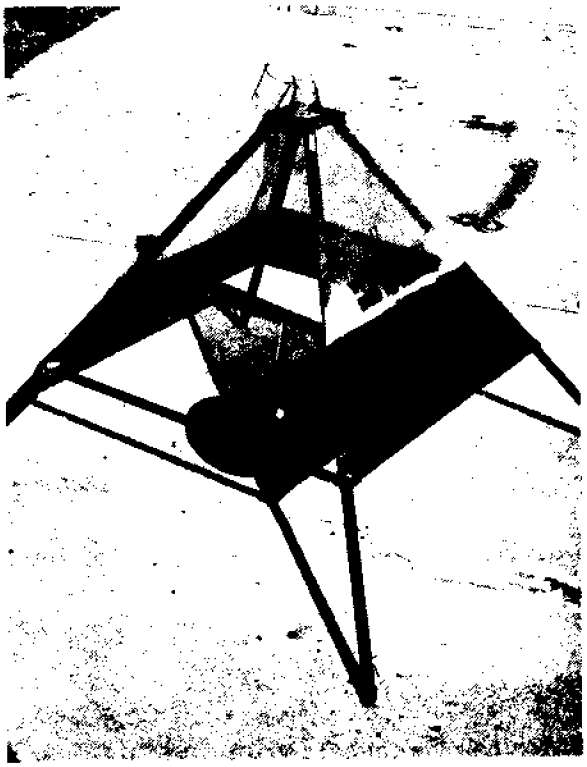


Figure 7

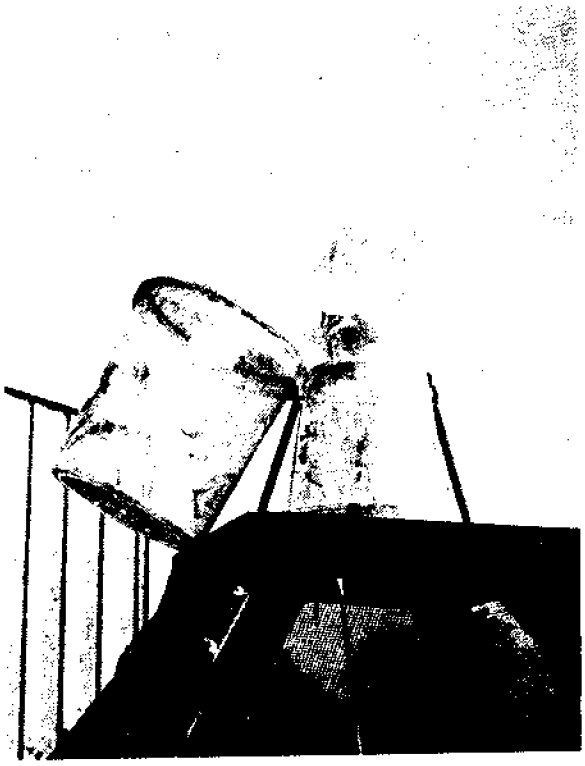


Figure 8

6.2 SAMPLING FOR CULICOIDES SAND FLIES

Larvae (and pupae)

Larval habitats for the major coastal pest species consists of mud found in salt marshes and the intertidal sand located along tidal creeks protected from violent wave action.

To sample for larvae the following materials are needed:

standard post-hole diggers
zip-top gallon plastic bags
large set of sieves (8" diam. x 4" deep)--10-, 16-, and 40-mesh
eye droppers
1000ml graduated cylinder
70% ethyl alcohol
saturated magnesium sulfate or sugar solution
vials or bottles (e.g. baby food bottles)
small wooden stakes
black magic marker
composition notebook

An area suspected of breeding Culicoides should be sampled for larvae and pupae. Samples should be uniform in size so that they can be compared on an equal basis. To accomplish this, a sample of mud or sand, 3 inches in diameter by 4 inches deep is obtained by using post-hole diggers. Once taken, the sample is placed into a one gallon, zip-top plastic bag, along with a small wooden stake containing a number. This number on the stake is the number of the sample taken. This number is recorded in a notebook along with a description of the habitat from which the sample was taken. The description should include the type and height of the vegetation, as well as the geographic location and date that the sample was taken.

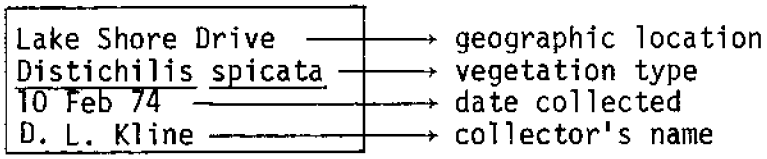
The samples are transported back to the laboratory in the plastic bags. At the laboratory a series of screens is set up in the following order starting with the bottom screen: 40-, 16-, and 10-mesh. The

vegetation in the sample is broken apart with the use of your hands, as the sample is washed by means of a garden hose (or a suitable alternative).

The sample is washed until all the mud is removed and the vegetation completely pulled apart and thoroughly cleaned. When this is done, the residue on the top screen is thrown away. The next step is to wash the residue found on the 16-mesh screen. After this is thoroughly washed, it too is thrown away. Next the residue on the 40-mesh screen is washed and then this residue is placed into a 1000ml cylinder (or similar tall glass jar). The cylinder is then filled with a saturated solution of either magnesium sulfate or sugar. The mixture is thoroughly stirred for several minutes; then the residue is allowed to settle. The larvae and pupae will float to the surface. Larvae can be seen swimming in a snake-like motion. The larvae and pupae are removed by means of an eyedropper. The larvae are put into a small dish of tap water to rinse off the solution.

When all the larvae are apparently removed, the mixture is again stirred up. Once again the larvae are removed and the number recorded. This process is repeated until no immatures are found for three consecutive times.

After all the immatures are rinsed, they are removed from the water and placed into a vial of 70% ethyl alcohol. A collector's label like the one illustrated below is also placed in the vial:



At locations where larvae are found, especially if found in abundance, emergence traps should be used. They provide useful data on what species are present and data on seasonal incidence and relative abundance.

Adult Sampling

Adult populations may be monitored by (1) emergence traps or (2) New Jersey light traps. Materials needed for each method are listed under that method. Sources where these materials may be obtained are listed at the end of the sampling section.

Emergence Traps

Materials needed:

- conical emergence traps
- sheet of cellulose acetate
- small paint roller
- small paint brush
- camel's-hair brush
- Varsol
- Bird Tanglefoot (or Castor oil)
- Roll of paper towels
- 70% ethyl alcohol
- Vials
- pint Mason jars
- White enamel pan
- eyedropper

Each trap consists of a cone of galvanized metal sheeting 25 inches in diameter at the base (area covered = 3.41 square feet) and 19 inches high, with a 2 inch diameter hole at the top. Around this hole we soldered on a ring (1 inch wide band) of galvanized metal sheeting. To this ring we attached (by means of sheet metal screws) a polyprene plastic pint jar cap with a 2-inch diameter hole in the center. This attachment allows for the Mason jar to be securely attached to the trap.

Before these traps can be used in the field, the jars must be prepared. The jars are prepared by placing strips of cellulose acetate

(4" x 8"), thinly coated with a sticky substance (Bird Tanglefoot or castor oil) in the jars. The inside bottom and lip of the jar are also coated with this sticky substance. The sticky substance is applied to the strips of acetate by means of a small paint roller, while the bottom and lip of the jars have the sticky substance painted on. With the jars prepared, the traps are placed in the field in areas believed (or shown by larval sampling) to breed Culicoides.

Capture of the adult Culicoides is accomplished by the flies being attracted to the light in the jar. The adults fly towards the light, and are trapped when they land on the sticky surfaces. The jars should be changed either once or twice a week. If Bird Tanglefoot is used the jars need to be changed only once a week. However, castor oil is only effective for about four days and therefore they should be changed twice a week. In either case the traps should be visited twice a week. At each visit the trap should be moved at least one yard. The best procedure is to have four basic positions at each location. At each visit the trap is rotated to a new position. Thus, it will take two weeks before the original position is used again. The position is changed at each visit because the larvae of some species have a tendency to congregate under the trap. By their congregating they present a false picture of what is emerging from that particular site.

To process collections, the jars are brought back to the laboratory. Using a camel's-hair brush, the specimens are removed from the jars and plastic strips by filling the jar with Varsol. The whole contents of the jar is emptied out into a white enamel pan. The specimens can be

identified by removing them by means of an eyedropper to a small dish and observing them under a dissecting microscope or a magnifying glass. Once identified the specimens may be discarded or preserved. In either case a record of the number of each species, as well as the date collected, should be made. To preserve, the specimens are removed from the Varsol by means of an eyedropper, and placed onto a piece of paper towel and allowed to dry. When dried they are removed to a vial containing 70% ethyl (or isopropyl) alcohol. A label like the one described for larval sampling should be included in the vial. Preserved (and properly labelled) specimens can be sent to specialists for verification of the identifications.

Light Traps

Materials needed:

New Jersey light trap with clock timer
fine mesh (16-) screen
5 oz. Dixie cups
plastic pint jar
Shell No Pest strip (Vapona)
vials
set of small (5" diameter) screens
graph paper

Where a source of electricity is available, another useful monitoring tool for adults is the New Jersey light trap. For Culicoides work, best results are obtained by replacing the regular screen with a 40-mesh screen. This is not an absolutely essential step, but it helps to prevent the small adults from escaping before they fall into the jar. The screen cone leads to a collecting jar, consisting of two parts: a pint plastic jar containing a one-inch wide piece of Vapona; the second part is a perforated (bottom) 5 oz. Dixie cup--the insects are collected in

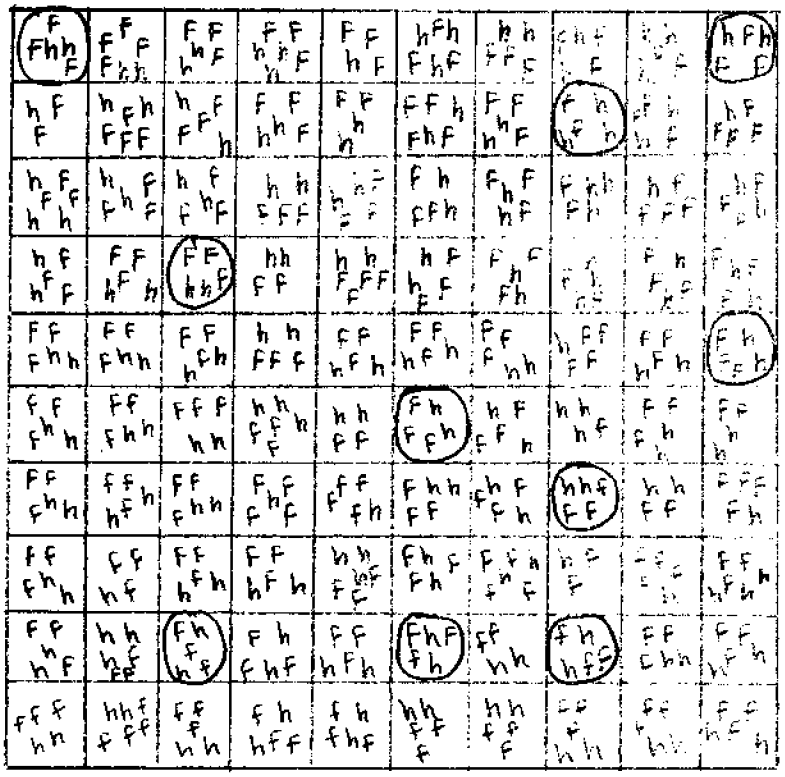
the cup. The perforations in the bottom of the cup allow the vapors from the pesticide strip to filter through and kill the insects in the cup.

The light traps should have on them either a clock timer or an electric eye that automatically turns it on at sunset and off at sunrise. The light trap should be operated all 7 days a week. An extra supply of perforated Dixie cups and 60-watt light bulbs should be taken along when checking the trap. The trap, if run continuously, should be checked at least twice a week, and preferably three times a week.

Logically, not only Culicoides are caught in the light traps. To process collections, it has been our practice to remove the mosquitoes first. The remaining collection is then processed through a series of screens (with meshes of 10-, 20-, and 60-). Nearly all the Culicoides are passed through the 10- and 20-mesh screens and are retained on the 60-mesh screen along with other small insects. With the larger insects removed, it is much easier to perform the final sorting under a low-power dissecting microscope (with practice this last step can be done with the unaided eye).

Since large numbers of Culicoides are usually collected in light traps, identification of every specimen is impractical. Therefore, after the final sorting is done, the remaining insects are uniformly spread out on a piece of graph paper. Between 1/4 and 1/25 of the collection is counted. The larger the sample, the lesser the amount counted. The specimens counted are also identified to species (see illustrated example). From these results the total population is determined with the use of the correct multiplication factor. This is best illustrated by means of an example:

Suppose, as in this example, after the final sorting, the collection covers 100 squares on a graph grid. Ten of those squares (those circled) are counted). The Culicoides in these squares are counted and identified to species (f=furens, h=hollensis).



If the results for these squares are: 30 furens and 20 hollensis, then the total population size would be 300 furens and 200 hollensis. These results are obtained by using the following formula:

$$\text{Total \# of flies of a species counted} \times \frac{\text{total \# of squares}}{\text{squares counted}}$$

$$= \text{population size}.$$

Using the above example:

$$30 \text{ furens} \times \frac{100 \text{ total squares}}{10 \text{ squares counted}} = 300 \text{ furens}$$

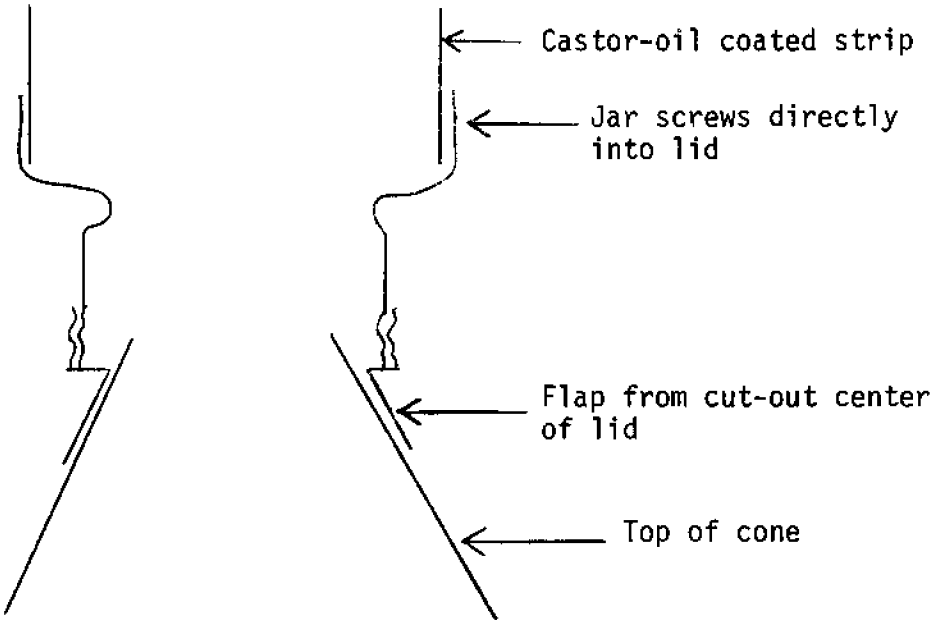
$$20 \text{ hollensis} \times \frac{100 \text{ total squares}}{10 \text{ squares counted}} = 200 \text{ hollensis}$$

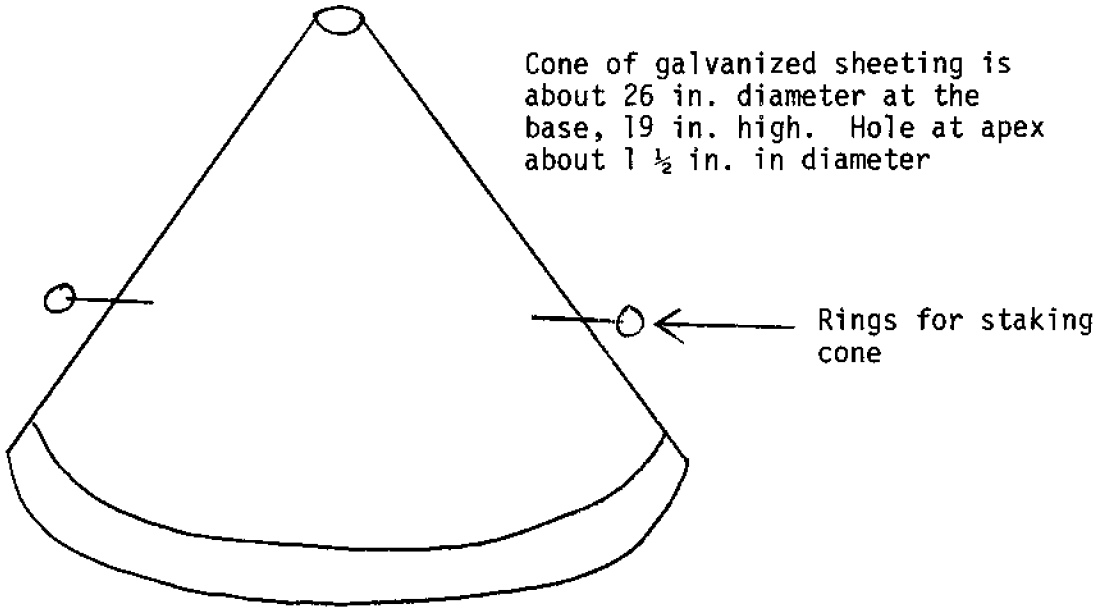
After the number of each species and the date they were collected is recorded in a notebook, the specimens may be discarded or preserved. If preserved they should be placed in vials of 70% ethyl alcohol in the manner described for emergence trap specimens.

Though light traps are good tools for routine survey work, they are not without their problems. They do require electricity, and this limits the areas that they may be used. Another disadvantage is that their catching efficiency is greatly reduced by adverse weather conditions. There is also a reduction in trap conditions during periods of full moon; the light of the moon competes (or interferes) with the light of the trap. Finally, while revealing broad seasonal trends, they do not yield information on where the Culicoides are breeding.

CULICOIDES EMERGENCE TRAP

Attach metal jar lid as shown. First cut out most of center of lid into a series of flaps with tin snips. Bend flaps back and tape to top of cone.





6.3 EVALUATION OF MOSQUITO PRODUCTION FROM COASTAL SALT MARSHES

The following is a stepwise procedure for systematic sampling of mosquito populations in salt marsh as a prerequisite for planning a water management control program. The procedure should be conducted during the interval Marsh 1st - October 31st for at least two years. Please read entire procedure carefully.

Part I - Use of slope index and flooding frequency to determine Aedes breeding potentials in large sections of salt marsh.

Step 1: A complete set of aerial photographs (preferred scale: 1 inch to 600 ft or 1 inch to 1000 ft) should be obtained and arranged together to form the entire county. The completed map can be placed on wall or table for reference. These aerial photographs may be ordered from: Eastern Lab, USDA, 45 S. French Broad Avenue, Asheville, North Carolina 28801.

Step 2: From the above photos and aerial reconnaisance (if possible), all salt marsh areas and adjacent woods should be divided into sections, in the most practical manner possible, for on-foot survey. Each section should be at least 500 acres in area. Each should be marked with stakes painted or taped with a standard, easily seen color and numbered (numbers either burned on or drawn on with black indelible ink). All sections should be drawn on aerial photographs.

Step 3: After all marsh sections have been delineated, a tide and rain gauge should be set up in each major river system or in an area that would represent at least 5 marsh sections. Data obtained from these gauges will be used to determine the frequency of flooding of the marsh. Light traps should also be set up in as many populated areas (major towns

and cities) near the marsh as possible to record the adult mosquito activity.

Step 4: A selected number of transect lines (the number depending on the size of the marsh section) should be marked out in each marsh section by means of 5 or 10 foot stakes painted white. These transect lines should extend across the marsh from the edge adjacent to the water to within the wooded uplands. The transect lines should be placed at least 200 feet apart (see Figure 1).

Step 5: The following surveys should be made along each transect:

(1) Site level survey (to be used in conjunction with rain data to determine the frequency of flooding/month for each site). The elevation of the marsh surface should be determined at each transect marker. The elevations can be calculated with a surveyor's transect and should be measured in relation to the marsh level at the tide gauge. The determination of the frequency of flooding/month for each site can be calculated by dividing the number of times the tide reached higher than the height of the site by the number of months the tide gauge was in operation. The assistance of engineering personnel in the local government unit should be sought.

(2) Breeding site and slope index survey. Each transect line should be surveyed for potential mosquito breeding sites. These are open areas within the marsh which contain patches of Distichlis spicata, Spartina patens and/or "matted down" Juncus. The topography of the area may range from being flat to being depressed and containing many pot holes. Each site should be marked and numbered with a 3 foot stake (painted yellow or orange). At each site, a slope index is calculated. This is done by dividing the depth of the water (deepest point) in the depression by the average distance from this point to the edge of the

depression (see Figure 2). If no water is present in the breeding site at time of discovery, an estimation of the depth can be made or it can be returned to at a later date following a period of heavy rain or major flood tide. Each transect line should be traversed at least once during the breeding site survey. If time allows, it can be checked again for sites that might have been overlooked the first time.

All slope index data can be collected during the first season of the mosquito survey program. It is desirable to collect this information at the beginning of the season after all transects have been established, since after all slope indices are determined, it will only be necessary to visit the marsh once a week for the remainder of the breeding season (March 1st - October 31st) to collect tide gauge data and 3 times a week to collect rain and light trap data.

Step 6: Determination of breeding potential. With the aid of tide and rain data collected for at least 2 seasons, the frequency of flooding per month for each site in the marsh sections can be calculated (see part 1 of Step 5). Once this has been done, an approximate breeding potential value for Aedes mosquitoes can be obtained by referring to Table 1.

Step 7: The arrangement of sites into breeding potential categories.

Category A: Sites with breeding potentials of 80% (or .80) or higher. These sites should be given first priority in Part II of survey procedure and when designing water management program.

Category B: Sites with breeding potentials of 50%-80%. These sites should be given lowest priority in Part II of survey.

Category C: Sites with breeding potentials of 50% or less. These sites should be given lowest priority in Part II of survey.

Part II - Larval survey and water management techniques.

A. Sites in Category A: These sites should be considered first in larval survey program, since they will most often produce the highest number of Aedes mosquitoes throughout the entire season.

In order to determine which sites in Category A yield the highest numbers of Aedes mosquitoes, they should be visited at least 3 times a week for the entire mosquito breeding season. At the first visit the surface area should be estimated and recorded. At each subsequent visit a water depth reading is taken and a breeding index calculated (see Table 2). Specimens can be collected by means of a water dipper attached to a long handle. Each breeding site should be dipped as thoroughly as possible, especially the edges where the water meets the vegetation and around clumps of vegetation that may be found towards the center (see Figure 3, procedure for dipping). The number of dips taken prior to the first positive dip (that in which larvae and/or pupae are found), depends on the size of the breeding site. From past experience it has been standard practice to take at least 20 dips in each site. If no larvae and/or pupae are found, a breeding index of zero is recorded for that visit and the site may be bypassed. If larvae and/or pupae are collected in one of the dips then take nine more dips. Of these ten dips, the total number of positive dips is recorded. All negative dips prior to the first positive dip are disregarded.

All larvae collected during this sampling procedure should be killed in boiling water and preserved in 80% ethyl alcohol for subsequent identification. Pupae should be placed in loosely corked vials 1/2 filled with water until emergence. Emerged adults should then be placed in an empty vial, loosely corked and supplied with a piece of cotton soaked in

sugar water. They should remain in these vials for at least one day, before being pinned, identified to species and recorded.

Once the location of the most prolific category A sites (those with the highest breeding indices), has been determined, water management techniques can be applied. The long term control program designed should be tailored to the number, location and distribution of those category A sites to be controlled.

Suggested Control Methods:

(1) Larvicide and fill - spot control should be applied to those Category A sites that can be conveniently reached by helicopter, boat, car or foot. If filling sites is impractical, a larvicide can be applied, when necessary.

(2) Impoundments - impoundments should be constructed in those areas only where a large, scattered cluster of category A sites exists.

(3) Ditching - this method should be used only if the above methods are rendered impractical. Its best use would be in areas where category A sites are in dense clusters, and can be ditched directly or nearly so. This can be done by excavating a ditch, by means of the shortest route possible, to the cluster and connecting the sites by means of short feather ditches.

B. Sites in Category B: No permanent control necessary here. These sites will occasionally produce large broods of Aedes mosquitoes. All marsh sections containing these sites should be monitored regularly for Aedes breeding. This can be done by checking weekly tide and rain gauge recordings. For example: an increase in flooding of a category B marsh section after a period of dryness (10-30 days) might produce a larger than normal brood of mosquitoes. With the knowledge of the weekly flooding

frequency at hand, a decision can be made as to whether or not it would be necessary to traverse the marsh area to assess the amount of breeding and to apply temporary control. The larval survey should be conducted in the same manner as for category A sites.

C. Sites in Category C: No permanent control necessary here. Sites in these sections of marsh rarely produce large broods of Aedes mosquitoes. They need only to be checked when a long period of drought (30 days or more) is followed by major flood tides and/or prolonged heavy rain. Larval survey and control procedures should be conducted in same manner as for category A sites.

Part III - Monitoring of adult populations.

Populations of adult mosquitoes should be monitored every mosquito breeding season in order to assess the change in their numbers and species composition. This is particularly important during the first two years of the larval sampling program. Light traps will usually detect any sharp increase in numbers of adults. This knowledge will help workers to properly time the application of temporary control measures with the time and location of highest mosquito activity. Although temporary control measures will be most important during the interval before water management techniques are applied, their continuance may be necessary afterwards when physical control methods become inefficient in preventing large broods of mosquitoes. Such times would be after hurricanes and other tropical storms have produced abnormally high tides which have flooded areas seldomly reached by normal flood tides during the breeding season. These upland areas often continue depressions which can yield high numbers of mosquitoes (usually Aedes species).

Table 1. Determination of Expected Breeding Potential for Aedes spp. (%)

SLOPE INDEX (S)	FREQUENCY OF FLOODING (F) 5	10	15	20	25	30	35
.05	100	65	30	5	0	0	0
.15	100	85	68	53	40	30	20
.25	100	87	72	61	52	44	37
.35	100	86	72	63	55	49	43
.45	100	85	71	62	55	50	45
.55	100	83	70	60	54	49	44
.65	100	81	67	58	52	47	42
.75	100	78	64	55	49	44	40
.85	100	75	61	52	46	41	37
.95	97	72	57	48	42	37	33
1.05	96	68	53	44	38	34	30
1.15	95	65	50	40	34	30	26
1.25	93	61	45	36	30	26	22

% EXPECTED BREEDING POTENTIAL

The above potential determined by following formula:

$$\underline{\text{Aedes}}\ \% = \left[\sin\left[(.78284 + (-.494)S + \left(\frac{5.206}{F}\right) + (-.0034)\left(\frac{F}{S}\right) + .024\ (.0001)\left(\frac{F}{S}\right)^2\ 57.29\right]\right]\ 100\ .$$

Table 2. Calculation of breeding index

$$\text{Breeding Index (B.I.)} = \frac{A \times P \times M}{T \times T \times 10}$$

where: A = surface area of body of water serving as effective breeding site in square feet,

P = number of positive dips obtained (those dips in which mosquito larvae and pupae are found),

M = total number of larvae and pupae obtained, and

T = total number of dips taken, disregarding all negative dips prior to the first positive dip.

Example: A = 100 sq ft,

P = 5 (5 positive dips out of a total of 10 taken),

M = 50, and

$$\text{B.I.} = \frac{100 \times 5 \times 50}{10 \times 10 \times 10} = \frac{25000}{1000} = 25.$$

Arrangement of Transects in Marsh Section

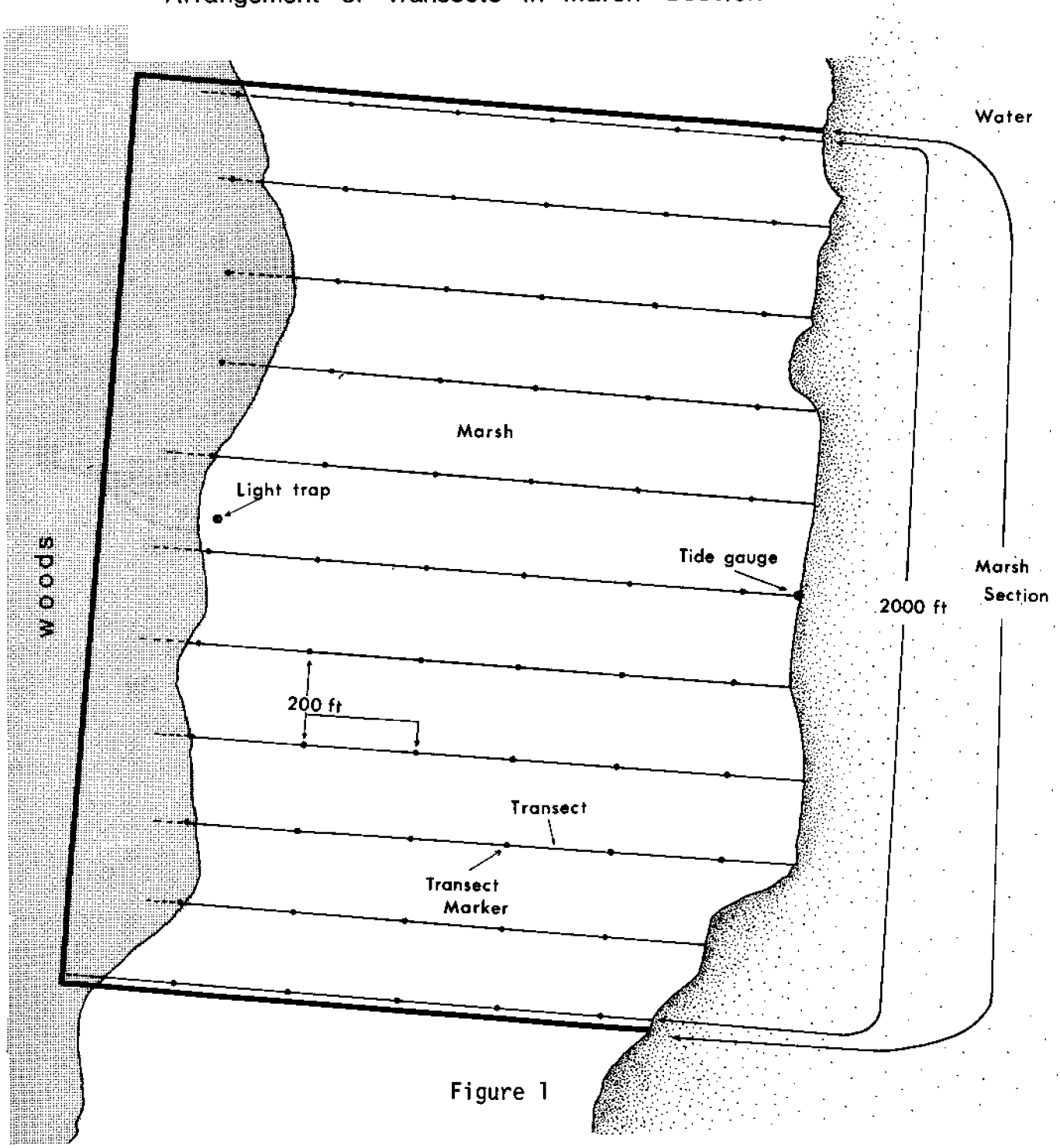
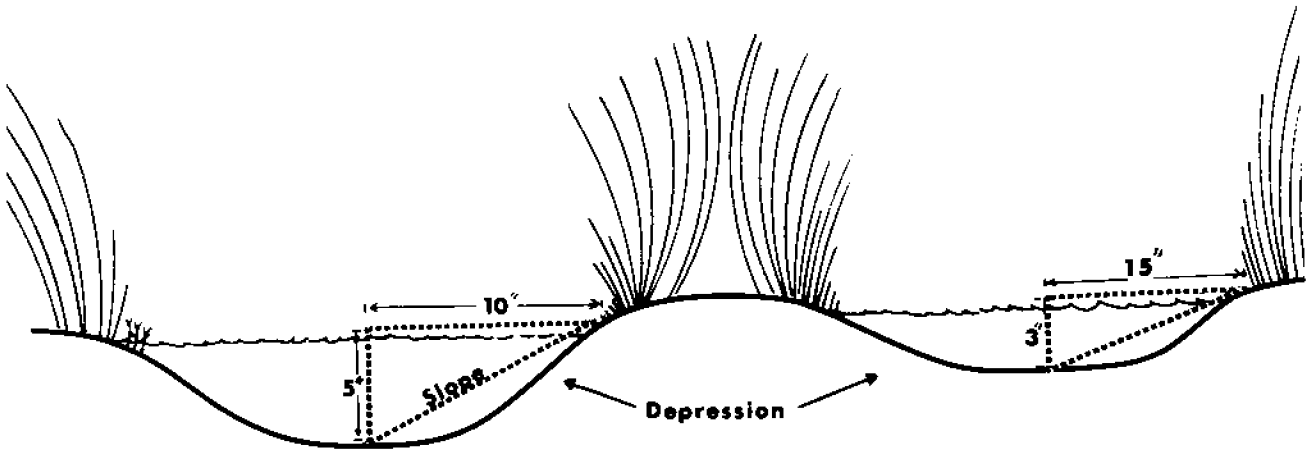


Figure 1



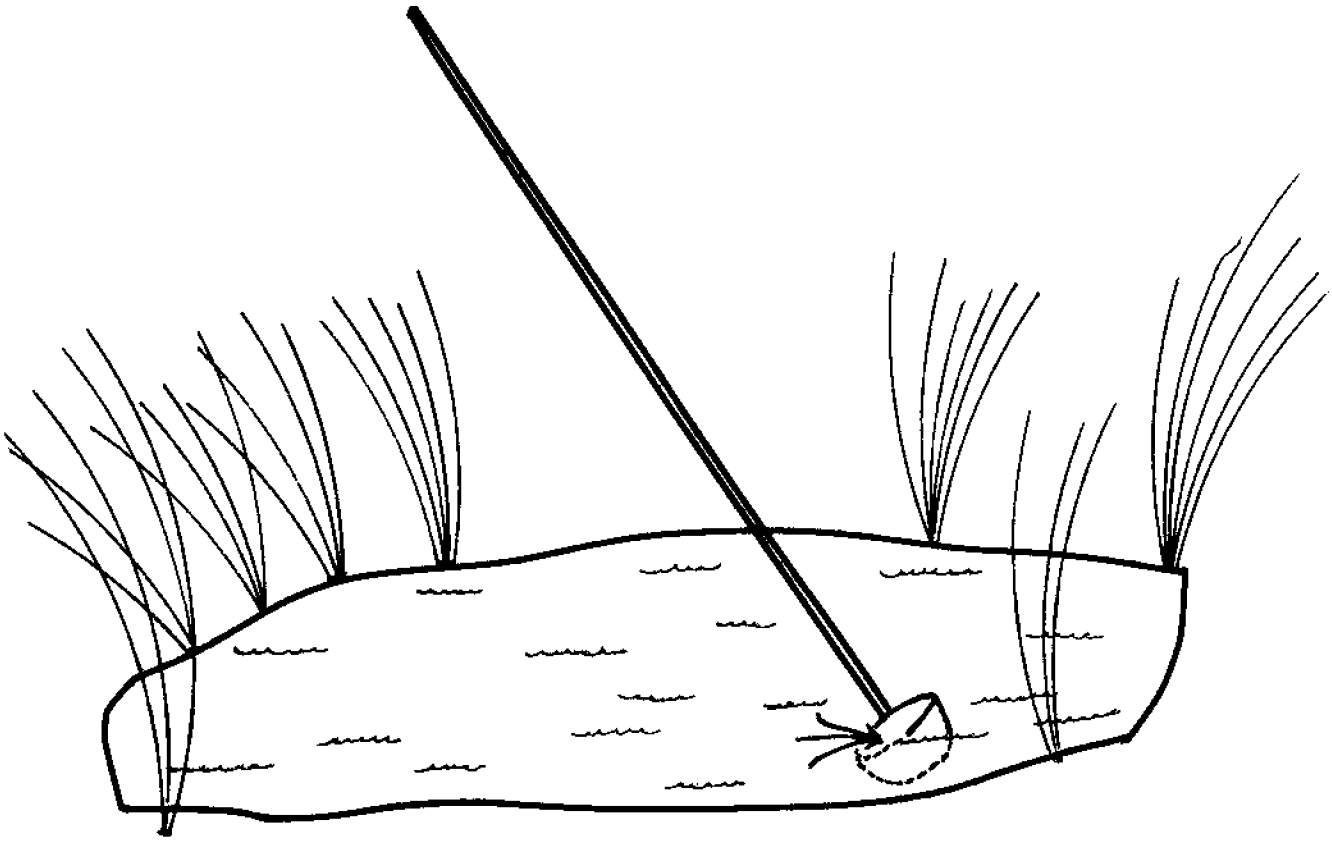
Slope Index = $\frac{5}{10}$ or .50

Slope Index = $\frac{3}{15}$ or .20

Determination of Slope Index

Figure 2

Procedure for Mosquito Dipping



PROCEDURE: Hold dipper at slight angle, gently draw water over edge of dipper. Fill to at least the 3/4 mark for each water sample.

Figure 3

7. PRINCIPLES OF CONTROL

7. PRINCIPLES OF CONTROL

Control of the coastal mosquitoes and biting flies can be accomplished by (see diagram):

(1) Cultural methods, such as source reduction which includes alteration of the marsh habitat by ditching or impoundment.

(2) Biological methods, including the use of natural and introduced species of parasites, predators and pathogens.

(3) Chemical methods, including insecticide applications against the adult and the larval stages of the insects.

Certain cultural methods of source reduction are widely practiced for mosquito control, although these practices obviously cause significant changes in the ecosystem. These are measures to eliminate the salt marsh mosquito breeding sites by ditching or impoundment. Excessive ditching destroys considerable amounts of marsh. In certain circumstances, selective ditching of the irregularly flooded high marsh can speed up the rate of water run off after unusually high tides or rainfall and as a result decrease the amount of mosquito production. In other situations, ditches may be useless. A careful study of the marsh characteristics and location of the mosquito breeding sites over at least 2 years is necessary before a decision can be made for or against ditching a particular section of marsh. It should be kept in mind that ditching is a permanent change in the habitat.

In some cases, impoundment is the source reduction method used to control salt marsh mosquitoes. The salt marsh Aedes mosquitoes require a cycle of drying and wetting for the eggs to hatch and therefore do not develop in impoundments. In this case, water is held on the marsh all the time by means of dikes. This, of course, destroys the marsh. A benefit is derived however. The impoundments are attractive habitats for wildlife. If the water in a salt marsh impoundment is allowed to become too fresh, then there is a risk that other kinds of mosquitoes will breed there. Proper management usually prevents that problem.

Other cultural and physical control methods should be included in a management program. Upland breeding of many mosquitoes can be controlled by eliminating such sources as artificial containers (old cans, tires, junk) and by filling or levelling potholes, depressions, ruts, etc. Elimination of these sources does not present any environmental problems and actually improves the environment by correcting the damage done by man. In some circumstances, the control of tabanid biting flies can be assisted by the use of traps and by the use of barrier plantings (trees and shrubs) to slow down the fly movement from the marsh into the upland where the people live.

Biological control agents exist naturally and have considerable effect on the number of mosquitoes and biting flies. These agents should be encouraged wherever possible. In certain fresh water systems it has been possible to introduce Gambusia fish to accomplish mosquito control, but this is not possible in the intermittently flooded marshes. At present, there are no practical biological control agents for release in the coastal habitats for mosquito and biting fly control. Perhaps, in the future, there will be such agents. Research is in progress on various fungi, viruses and protozoans in hope of finding a practical biological control agent.

Because of the limitations to cultural and biological control methods, chemical measures will continue to be used. Personal protection, by using repellents, is often the best solution in a locality. A new class of chemicals, called developmental inhibitors or growth regulators, are beginning to be used. These chemicals are quite specific for insects and relatively non-toxic to most other animals. In the coastal habitats, however, extra caution is needed since organisms which are closely related to insects (such as shrimp) might be adversely affected.

The most commonly used chemical measures are insecticides. These may be directed against the larva (larviciding) or against the adult insect (adulticiding). Application may be by ground equipment or

by aircraft, in either case. Aircraft application offers the advantage of allowing treatment of otherwise inaccessible areas. However, it is often difficult to keep the insecticide only in the target area. Treatment by ground equipment is the "backbone" of most control operations.

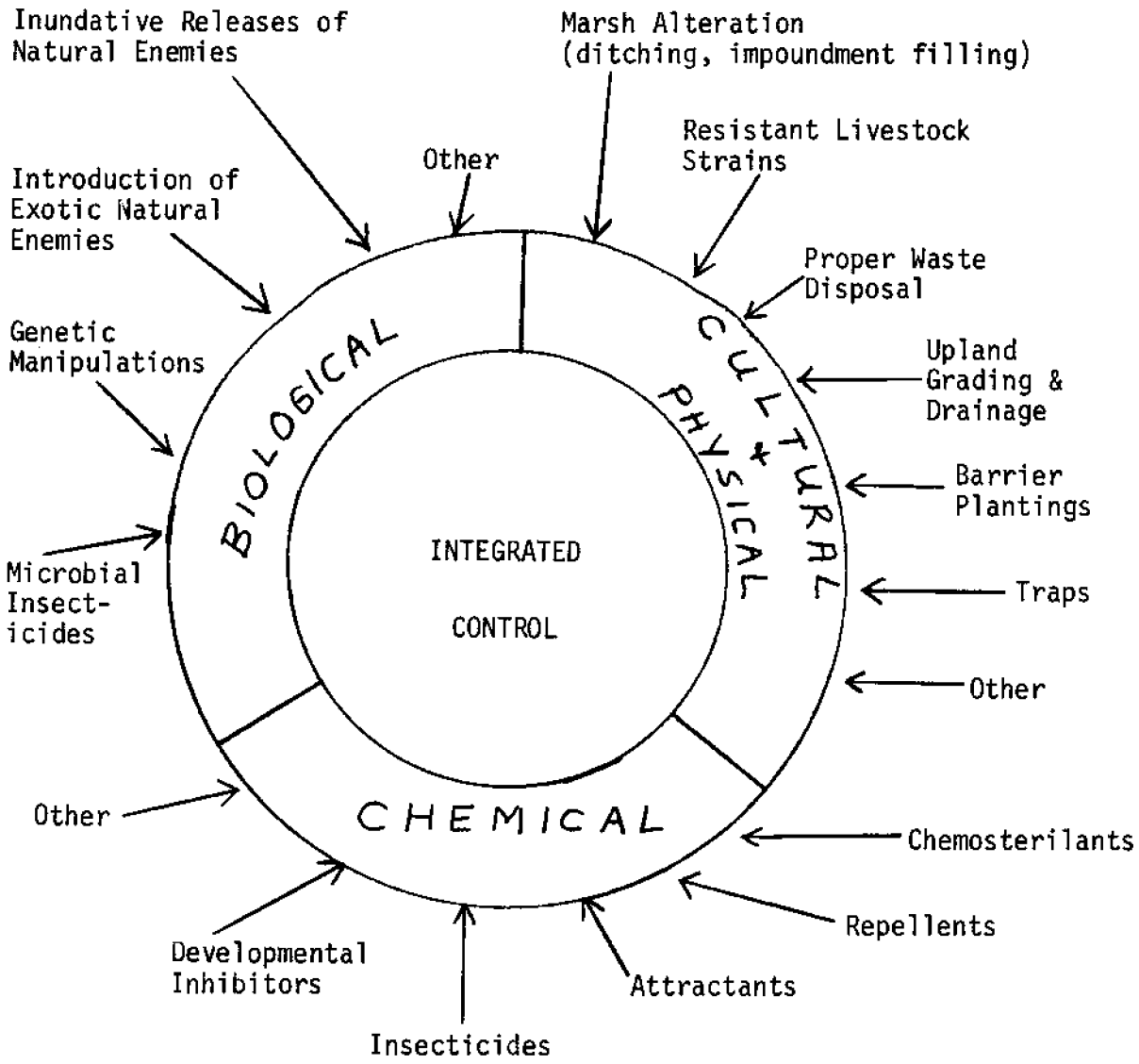
Used wisely, at the proper time, in the proper place, and with the proper chemicals, the use of insecticides can be accomplished with no harm to the environment. Improper use can be disastrous. A few chemicals may be safely applied to specific mosquito breeding sites in the marshes, particularly along the upland margins. These same chemicals, as well as a few others, may be used in upland breeding areas. Knowledge of the proper chemical and the proper dosage rate is essential. Adulticiding can be accomplished safely if all precautions and proper chemicals are used. ULV (ultra low volume) application equipment is widely used for this purpose. For both larviciding and adulticiding for mosquito control, chemicals are now being recommended which break down relatively rapidly in the environment. Chemicals are not usually satisfactory for the control of the larvae of tabanids and Culicoides sand flies which are in the very moist soil. Adulticiding can be done, however.

Proper use of any control measures requires an inspection and insect monitoring program to determine what species of insects are the

problem, when are they a problem and where are they breeding. Further, the monitoring program is needed to determine whether or not the control measures were effective.

The chemical control measures must be adopted with extreme caution and be integrated with the source reduction methods (and eventually biological methods) into an integrated program for management of the mosquito and biting fly problem. There is no single magic control measure. Over reliance on one method is unsound and will produce unsatisfactory results. The proper mix of methods will vary according to the local conditions and adjustments may be required in different years.

With even the best planned and executed program, there will be mosquitoes and biting flies present. The object of a management program is to reduce the number to a tolerable level. There is no alternative; elimination of these pests is not practical or feasible. Public understanding of the complexities of the problem is needed for a control program to function properly. Therefore, an important part of any control program is public education and cooperation. The citizens should be educated on the nature of the insect problem, on the kinds of control measures used and on the concept of insect pest management rather than elimination.



CONTROL METHODS AND TECHNIQUES TO BE CONSIDERED FOR INTEGRATION INTO A PROGRAM FOR THE CONTROL OF COASTAL BITING FLIES AND MOSQUITOES AFFECTING MAN AND ANIMALS.

8. CONTROL BY SOURCE REDUCTION

8. CONTROL BY SOURCE REDUCTION

8.1 SALT MARSH DITCHING

History

Salt marsh mosquito control activities began in North Carolina in the late 1950's as a result of legislative action directing the State Board of Health to implement a mosquito control program. The purpose of the program was to control the vast hordes of mosquitoes causing nuisance and economic losses in the Coastal Counties. Fogging and spraying of the adult mosquitoes was initiated as an emergency measure to offer some temporary relief in the affected counties. It was soon realized that more permanent control measures had to be inacted.

Water management on salt marshes in New Jersey, Delaware and Florida had proved effective for the control of Aedes sollicitans and Aedes taeniorhynchus the same two mosquitoes causing the problems along the N. C. coast. Water management was accomplished in these states by systems of ditches designed to remove surface water from the marshes in 5-7 days causing the destruction of the mosquito larval in the aquatic stages. The big problem with these ditches was maintenance, and frequent cleaning was necessary and expensive. Heavy equipment moving about on the fragile marshes often created additional breeding sites while attempting to re-clean the existing mosquito control ditches. The ditches were small, 18-24 inches wide and 18-24 inches deep. It seemed reasonable that larger ditches 6-8 feet wide and 3-4 feet deep, although more expensive to construct would be relatively maintenance free and these dimensions were adopted for the salt marsh work in N. C. on an experimental basis. The ditches were spaced 150-500 feet apart depending primarily on soil types; the tighter the soil, the closer together the ditches were placed. Usually the pattern was parallel ditches with laterals extended to depressed areas

such as pot holes or like depressions known to hold water and breed mosquitoes.

In the initial stages of the program, a great deal of time was spent in entomological surveys to determine breeding sites in the marshes before the drainage system was layed out and construction started. It became obvious after several years of walking marshes and locating breeding sites that certain sections of a marsh were frequent and heavy breeders of mosquitoes while other areas were not ordinarily heavy breeders. With practice, heavy breeding areas could be identified by vegetation, soil types, etc. and post construction entomological surveys became less frequent and actual ditch contruction was accelerated. Continuous surveys and studies, mostly by oversvation, were conducted by engineers, sanitarians and entomologists to determine the effectiveness of the ditches. Over the years, it became apparent that the ditches required little maintenance and that they did effectively control the two target species of mosquitoes.

It was discovered very early in the program that ditches opening into shallow bays or sounds would not stay open, so all major outlets were cut into deep waters, usually at the head of creeks. Another problem that has developed is the growth of woody vegetation along the banks of the older ditches which interferes with access by boat for survalence and inspection, but does not interfere with drainage.

Present Program

Seventeen years after the first ditches were cut in N. C. by the State Board of Health for mosquito control these ditches remain in excellent condition. Therefore it seems reasonable to state that the 8 ft x 4 ft ditch is relatively maintenance free. These ditches continue to affect both surface and subsurface drainage up to a distance of 200 feet

perpendicular to their banks along both sides, providing good water management for mosquito control. This 8 ft x 4 ft ditch is a standard today and only occasionally altered.

In the past two years, the interest in the total environment has brought the marshlands into a new focus. These lands, long considered as wastelands by most, have been recognized as valuable. Conservation and resource management agencies are studying the marshes as never before to determine the best uses of this valuable resource.

The outlook for the salt marsh mosquito control program, of necessity, has changed. The total resources involved are presently given more consideration by mosquito control workers than in the past. For example, the past system of "parallel ditching" has been replaced by "selective ditching". Selective ditching is based on the sound concepts of entomological and biological surveys and research findings, prior to any construction work. All resources are evaluated to determine any detrimental effects that might result from the construction of ditches or dikes. Tolerance levels for the native population of an area and tourists are considered. The desired percentage of control becomes a question of the degree of public tolerance of mosquitoes and the cost of effecting this control level in a given area. "Selective ditching", with other modifications, will no doubt continue to be a useful means of controlling the salt marsh mosquitoes.

Explanation of Diagrams

Sheet No. 1 - "Parallel Ditching" System

A hypothetical salt marsh adjacent to a community with agricultural and timber lands a part of the immediate environment. The heavy breeding areas in the salt marsh as well as potential breeding areas are located

by entomological surveys and marked on maps and staked on the marsh. Ditches are layed out by engineers and constructed by draglines. In this system of ditching, all the marsh is considered as a potential breeding area and water management is planned to take care of the entire marsh indefinitely. This design is based on the fact that marshlands are constantly changing and a major storm can change the normal breeding areas completely. Note that all marsh drainage is north into the rim ditch which in turn drains the runoff from the higher land (woods, fields) into the deep waters of the shough and creek. The sand bank along the sound prohibits drainage directly into the sound waters. Usually, extensive breeding occurs behind the sand banks and along the upper edge of the salt marsh where the rim ditch is normally located. Generally, breeding in the open marsh is spotted. Sheet No. 3 shows the cross-section of one of these ditches.

Sheet No. 2 - "Salt Marsh Impoundment"

Sheet No. 2 shows the very same environment as Sheet No. 1. However, the salt marsh impoundment method is used for water management in controlling mosquito breeding. It is more efficient than the ditching methods but more expensive to construct and maintain. It has the advantage of multiple use in recreation and wildlife propagation.

Sheet No. 3 - "Cross-Sections"

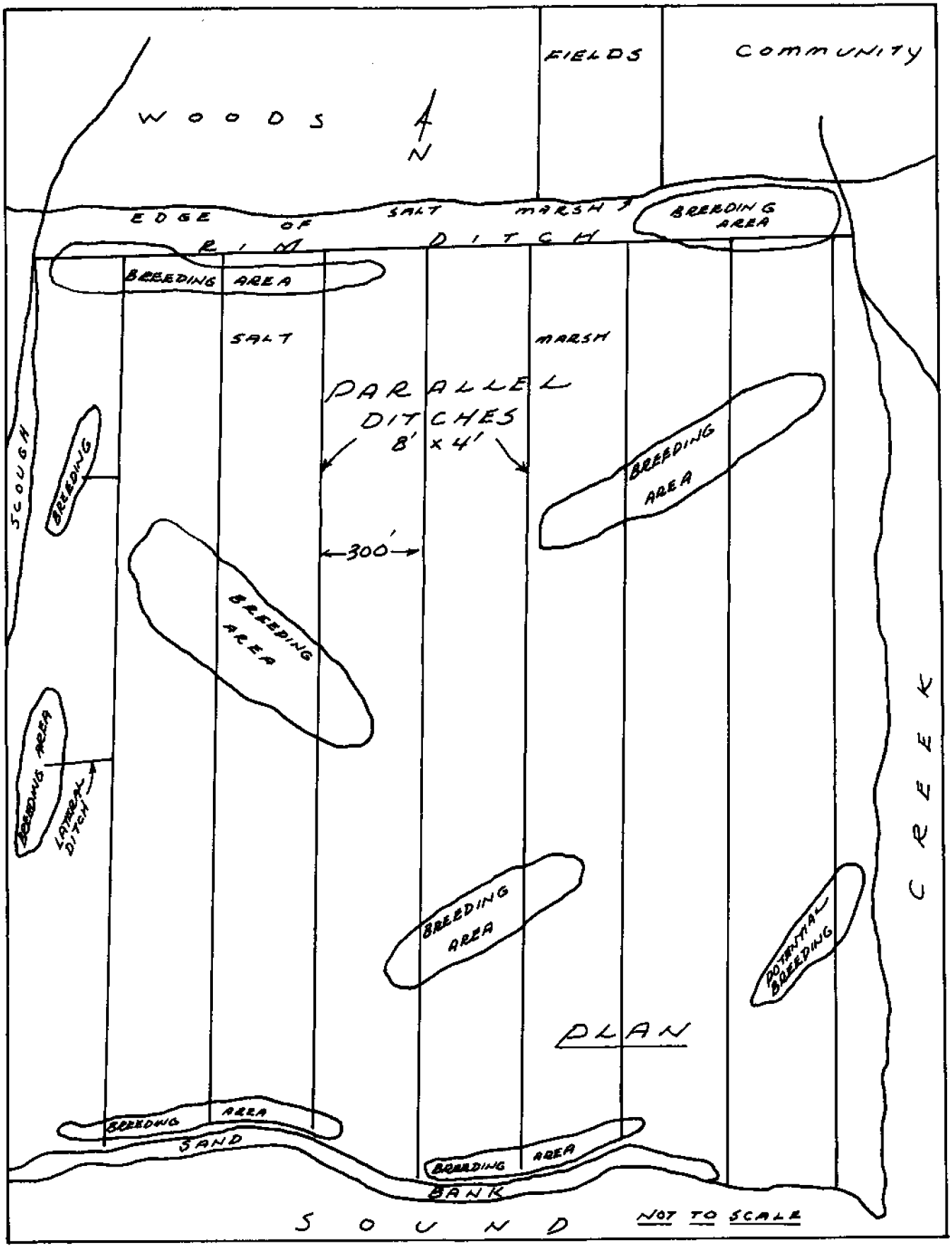
Shows cross-section of both ditches and dikes of Sheets No. 1, 2, and 4.

Sheet No. 4 - "Selective Ditching" System

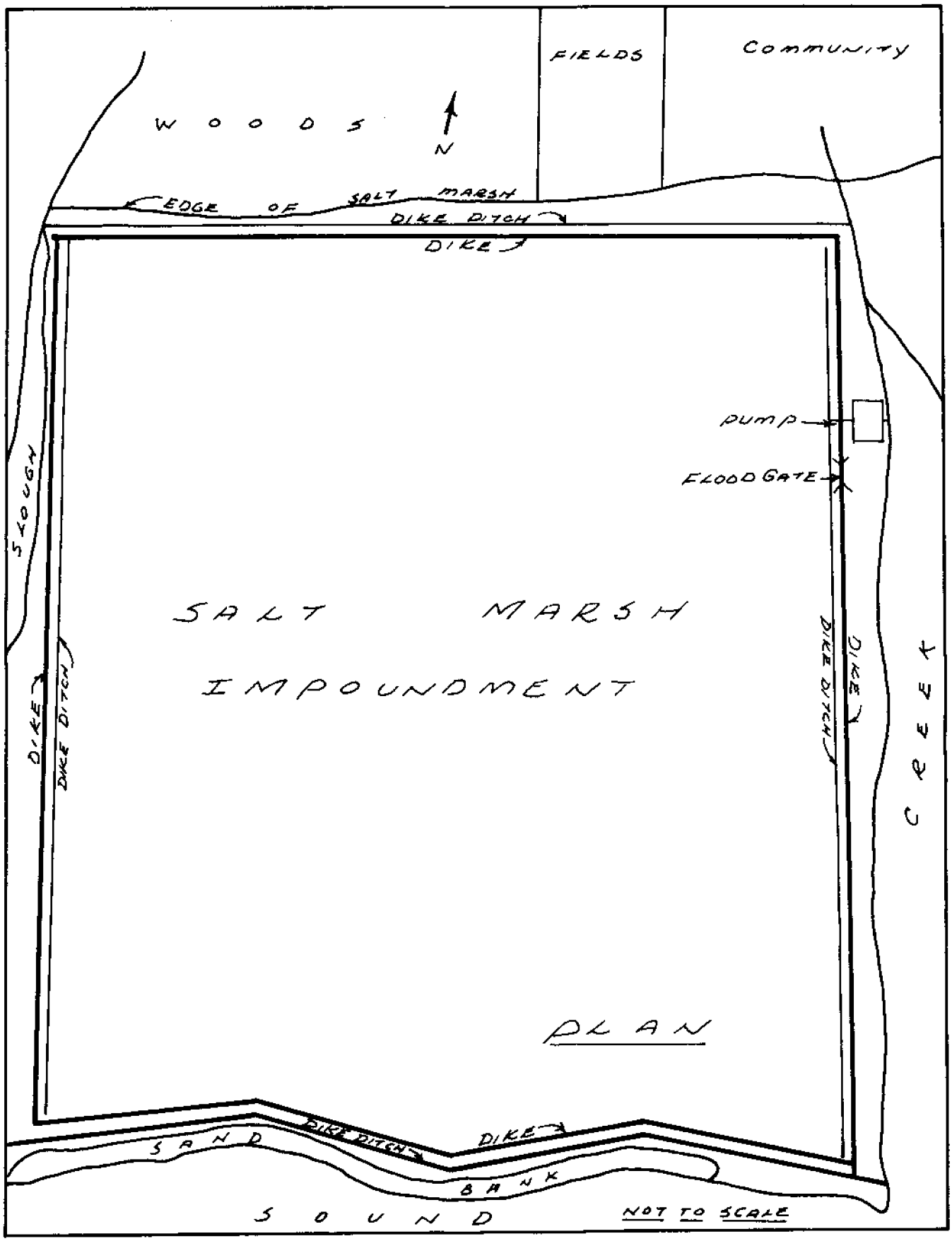
Shows same environment as Sheets No. 1 and 2. Entomological surveys determine the heavy breeding areas and they are located on maps and staked

in the marsh just as in "parallel ditching". In "selective ditching" only current breeding areas are considered and treated. The entire marsh is not considered as a potential breeding area as in "parallel ditching". "Selective ditching" requires much more pre-construction and post-construction surveys and survalence.

SHEET NO. 1

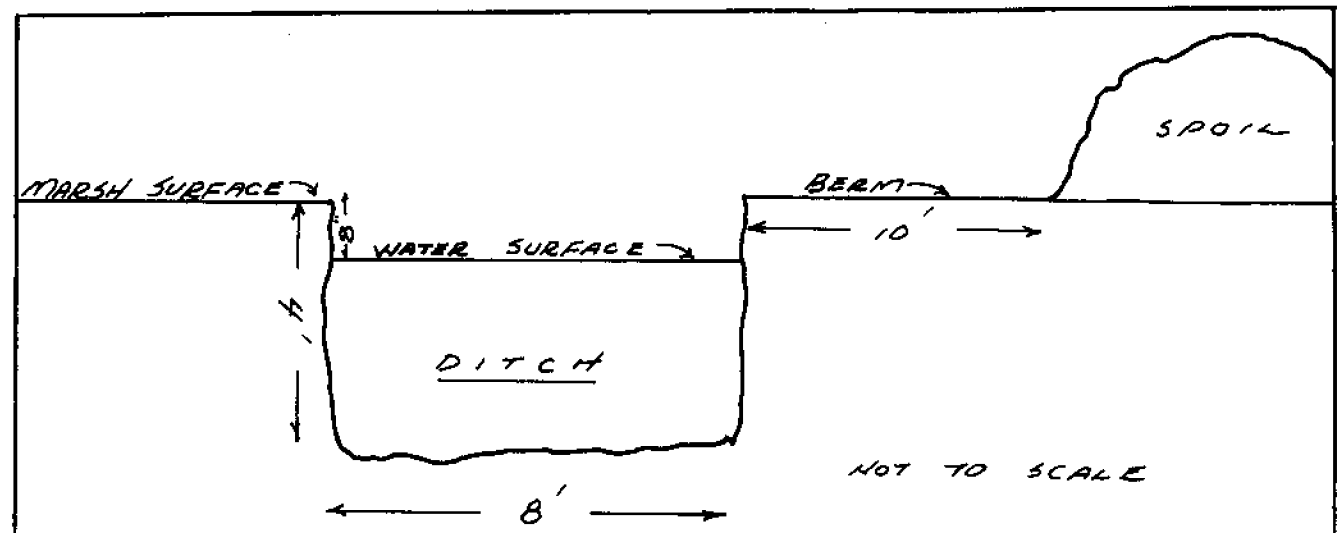

WOODS
N
FIELDS
COMMUNITY
EDGE OF SALT MARSH
RIM DITCH
BREEDING AREA
BREEDING AREA
SALT MARSH
PARALLEL DITCHES 8' x 4'
SCOUGH
BREEDING
BREEDING AREA
BREEDING AREA
300'
BREEDING AREA
LATERAL DITCH
BREEDING AREA
BREEDING AREA
POTENTIAL BREEDING
CREEK
PLAN
BREEDING AREA
SAND
BANK
BREEDING AREA
SOUND
NOT TO SCALE

SHEET NO. 2

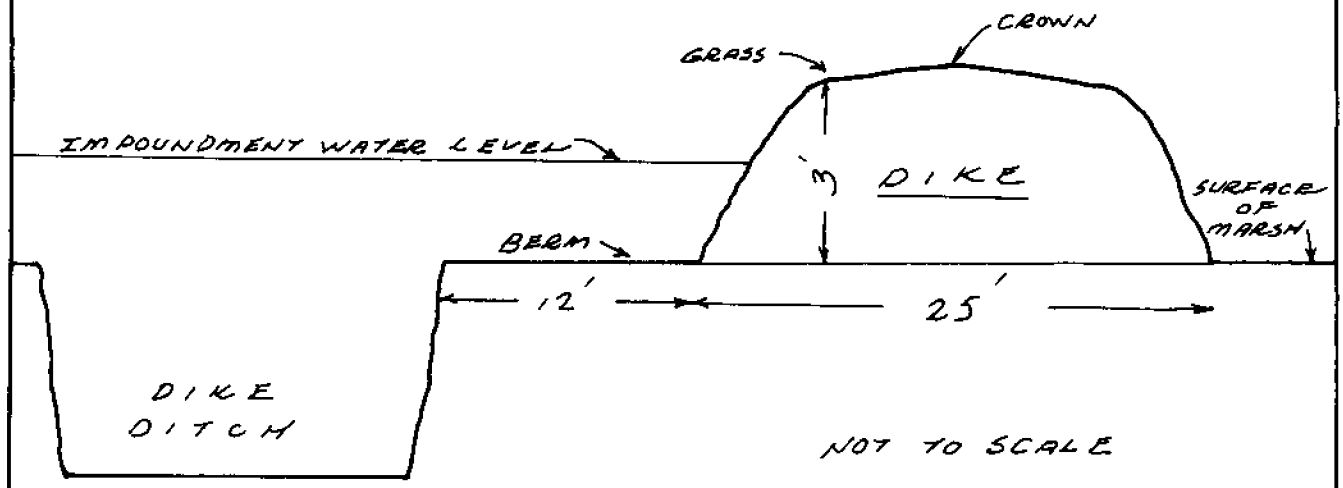


PLAN

SHEET NO. 3

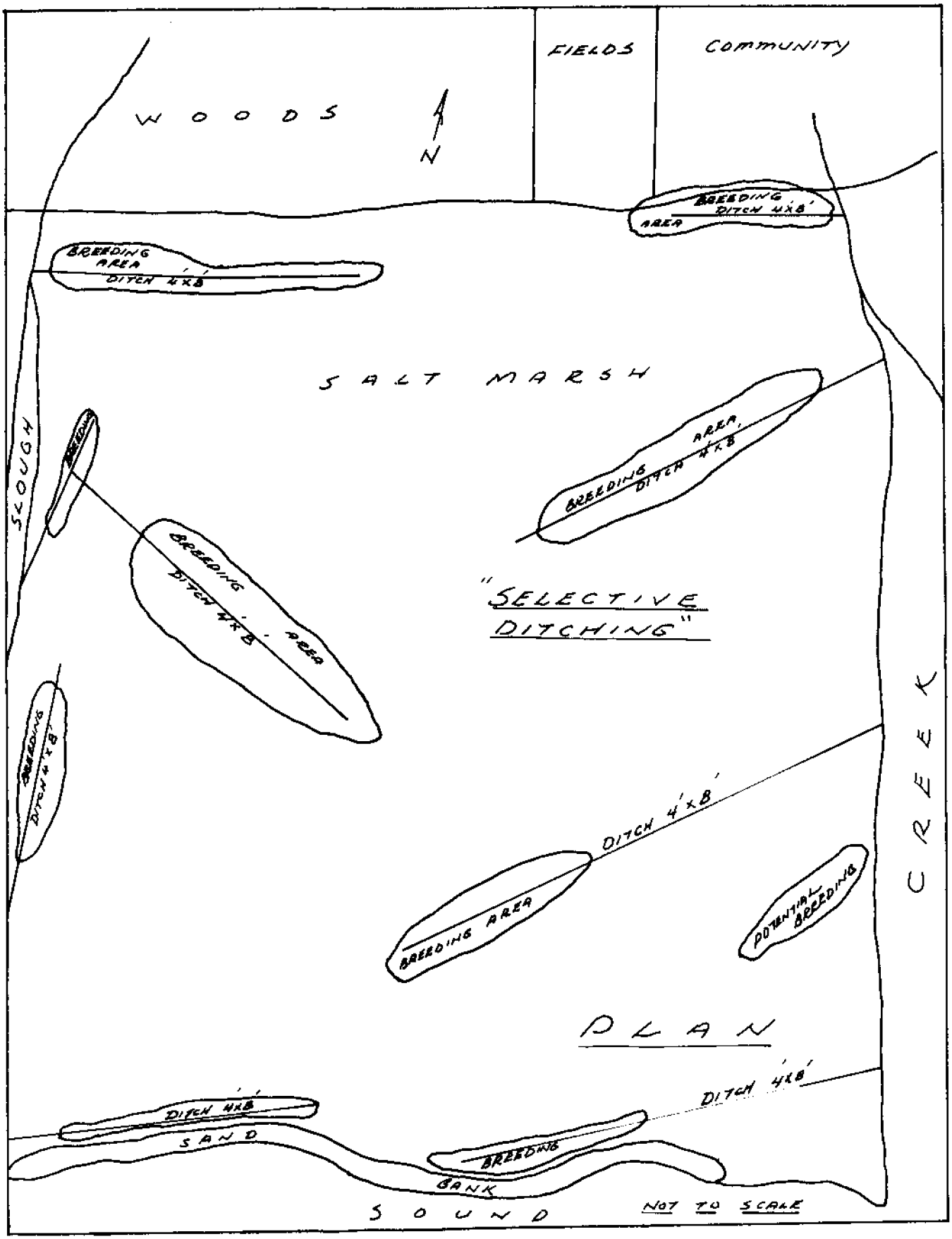


DITCH CROSS SECTION



DIKE CROSS SECTION

SHEET NO. 4


WOODS
N
FIELDS
COMMUNITY
BREEDING AREA
DITCH 4'x8'
BREEDING AREA
DITCH 4'x8'
SALT MARSH
SLOUGH
BREEDING AREA
DITCH 4'x8'
BREEDING AREA
DITCH 4'x8'
"SELECTIVE DITCHING"
BREEDING AREA
DITCH 4'x8'
DITCH 4'x8'
BREEDING AREA
POTENTIAL BREEDING
CREEK
PLAN
DITCH 4'x8'
DITCH 4'x8'
SAND
BREEDING
BANK
SOUND
NOT TO SCALE

8.2 SALT MARSH IMPOUNDMENT

The first experimental impoundment was constructed in North Carolina on Wildlife Resources Commission land in Pamlico County. It was only 38 acres, but it was such a tremendous success in controling mosquitoes and providing wildlife habitat that another was planned and completed in the next 18 months. The second impoundment was 800 acres in size, and located at Pamlico Point in Pamlico County. It provided almost 100 percent control of the major salt marsh Aedes mosquitoes.

As a result of the efficiency of these two experimental impoundments in providing wildlife habitat and mosquito control, approximately 6,000 acres of additional impoundments have been constructed to date. They have become extremely popular to sportsmen, waterfowl biologists and mosquito control workers along the coast. In recent years, as the true value of the marshes has been revealed, the proper place for the impoundment in the total utilization of the marshes is being questioned. As in any alteration of nature by man, some species of plant and animal life are inhanced at the detriment of other species. Impoundments do play a very important role in providing varied wildlife habitat, recreation, and mosquito control and will, no doubt, in the future be an important factor in planning marsh utilization. Their use in the production of fish, crabs, shrimp and oysters shows good possibilities (B. Robert Lunz, 1967).

Construction, Operation and Maintenance

A salt marsh impoundment is defined as a shallow lake with an average depth of 12-18 inches, created or constructed on a salt marsh by diking and flooding to control the breeding of the principle species of salt marsh mosquitoes and to provide habitat for waterfowl and other wildlife.

Generally speaking, an impoundment can be constructed on any irregularly flooded marsh. Irregularly shaped marshes with numerous creeks and sloughs and with fine silt soils are the most expensive to dike and maintain and usually are not considered feasible for impounding for mosquito control. Other methods of control are much more practical. Marshes, regularly shaped, to allow the most acreage for the least dike footage; with sandy clay or organic soils; and no creeks or sloughs are by far the most economical to impound. It is important that the salinity of the estuarine waters be consistently high enough (15,000-20,000 ppm) to eliminate all freshwater species of mosquitoes.

The most efficient and economical width for dikes, generally speaking, is 15-25 feet, depending on the location along the estuary, soil types, and maintenance plans. The final height of the dike above marsh elevation is normally 2.5-3 feet. Since 1.5 feet of water is the maximum required at any time to provide ideal waterfowl habitat and mosquito control, the above dike height is more than adequate and allows for some anticipated erosion. The initial height of the dike, during the construction phase, varies due to soil types and construction methods, but is generally 4-5 feet. This allows an average of 30-40% for settlement and compaction over a 6-9 month period during which 80-100% will occur.

At least part of the dike ditch (excavated to obtain soil for dike construction) should be on the inside of the impoundment to provide deep water for marine life and waterfowl when the impoundment is drained or the water level becomes too low due to pump break downs or poor management.

Several things must be considered in selecting and placing flood gates and pumping equipment. The size and shape of the impoundment are the main factors to consider in the planning stage. It has been determined by experience that it is very difficult to manage over 200 acres with one

pump, so that larger impoundments should be divided into sections of 200 acres or less. These larger impoundments can still be managed with a single pump with proper placement of section dikes and flood gates. A 16-18 inch diameter electric pump, like those used by farmers for watering and de-watering fields are very effective for impoundment management. Where electricity is not available, a homemade gasoline powered pump, 18-24 inches in diameter and turning 700-900 RPM works very well. Metal flood gates, treated to withstand salt, sand and sun, last much longer than wooden gates and cost about the same installed. These flood gates are designed and placed to regulate water flowing in and out of the impoundment, thus controling the desired water level.

The types of vegetation, both submergent and emergent, that appear in the impoundment are of little or no importance in mosquito control but of utmost importance in waterfowl and wildlife management. Some duckfoods usually occur naturally, but additional food plants must be introduced and nurtured for best results. Adequate emergent vegetate for cover and concealment is important in managing the impoundment for wildlife and waterfowl habitats (Florschutz, 1968).

Newly constructed dikes should be seeded or sprigged with grass to help prevent erosion until natural grasses and vegetation have become established. Soil samples of the dike material are necessary to determine the proper fertilization program and planting procedures. The Soil Conservation Service and Agricultural Extension Agents can provide this information.

The N. C. Wildlife Resources Commission as well as some private landowners are presently experimenting with draining impoundments and planting, millet, corn, etc. during the summer months and reflooding in the fall. This practice is being watched very closely from the standpoint of mosquito control, but no conclusions have been arrived at to date. This practice does

appear to have mint in providing food and cover for waterfowl and various species of wildlife. It is totally destructive to marine life in the impoundment.

Some Facts about Impoundments

In 1970, it cost approximately $35 per acre to build an impoundment on a typical salt marsh. It cost approximately $22 per acre to ditch the same marsh.

Impoundments give almost 100% control of the salt marsh mosquitoes Aedes sollicitans and Aedes taeniorhynchus which are the two target species in the salt marsh control program. Drainage ditches do not give as high a rate of control.

Maintenance of impoundments is expensive. Ditches are almost maintenance free.

Not all marshes can be economically impounded. It is economical to ditch any marsh.

Waterfowl on Impoundments

Ducks -- black mallard, pintails, teal, wood duck, geese widgons, canvasbacks, scaup, redhead, ruddy duck, buffle head, etc.

Other birds -- herons, egrets, yellowlegs, gulls, osprey, rails, etc.

Wildlife -- mink, otter, muskrats, raccoons, bear.

Marine life -- crabs, snails, shrimp, fish, oysters.

Natural vegetation -- bulrush, threesquare, spike rush, smart weed, widgeon grass, sago, southern pond weed, wild celery, redhead grass, ell grass.

Impoundments control mosquitoes (salt marsh varieties) such as Aedes by eliminating the alternate wet-dry habitat necessary for breeding. Impoundments control fresh water breeding by pumping brackish water into the environment.

Florschutz, O. 1968. Species and successional control of undesirable marsh vegetation. N. C. Dept. of Natural Resources, Wildlife Resources Commission.

G. Robert Lunz, 1967. Farming the salt marshes. Preceedings of the marsh and estuary management symposium. Louisiana State University, Baton Rouge.

8.3 FRESH WATER DRAINAGE

Due to the flat terrain and prevalent high water table in the coastal plains area of North Carolina, a serious mosquito problem often exists. The Solid Waste and Vector Control Branch, Department of Human Resources advocates major emphasis be placed on source reduction in its mosquito abatement effort. Environmental cleanup of solid waste which holds water and drainage in areas where needed, especially plateau areas, are the methods used most.

Invariably, the areas that have serious drainage problems have mosquito problems. However, drainage affects many resources and problems other than mosquitoes and should be done only after the total environmental effects have been considered.

Drainage projects on large watersheds are designed to accomplish the desired drainage with the least detrimental effect to fish and wildlife. The following methods are those used by County Mosquito Control Programs to accomplish stream drainage. A brief analysis follows each technique listed. Analysis is, at this time, based on field observations of past projects and research is needed to document these observations.

I. Follow old stream-bed (no straightening)

The benefits of this are apparent. On stream bends, the natural action of flowing water will "kick out" holes on one side and "build-up" sand base on the other. This is necessary to produce spawning areas and also to create deep pools for fish survival during the hot dry season.

II. Dip out stream-bed sediments only to water-bearing sand level and do not widen stream past its natural channel width

This is a very important concept in that it lessens stream-bed erosion, decreases silt load during flooding, allows for quicker bank

stabilization and has little, if any, effect on draining adjacent wetlands through lateral drainage.

Stream-bed erosion and silt load are both reduced because removing only the fill lying over the original stream-bed, restores the stream to its "natural" condition (or to a state similar to what it was prior to the beginning of rapid sediment build-up). The old stream-bed substrate is probably more stabilized and much less prone to erosive action, therefore, siltation during flooding is lessened. The silt load is also lessened because the stream is allowed to overflow its banks on to the flood-plain, depositing much of its silt on either side of the flood-plain instead of carrying it all downstream, as most SCS and Corps Projects do, to some point where a continuous build-up occurs. Considering Coastal Plain Drainage Systems, silt build-up usually occurs in the estuarine areas resulting in severe destruction of fish and shellfish habitats.

Bank stabilization and natural revegetation is relatively rapid because the spoils taken from the stream are high in organic content and plant life readily grows in this type of substrate. This differs from Corps and SCS Projects in that spoils from their channelizing efforts are primarily sand and clay deposits which are comparatively quite unfavorable for initial plant growth. Sand and clay spoils are the result of vast over-digging of the stream-bed and new channel.

Lateral drainage is only slightly affected because spoil removal does not extend below the water bearing sand level. Lateral movement of ground water and sub-surface water to the stream-bed is possibly very slight and during the wet season the adjacent flood-plain can hold enough surface water for an adequate wetland wildlife habitat. Contrast this with Corps and SCS Projects which usually drain adjacent wetlands.

III. Cut right-of-way only on one side of stream, leaving as many large mast-producing trees as possible and clearing only to width that will allow dragline to operate

This technique has several plus points when compared to the general practice of clearing and dumping spoils on both sides of the stream. The side which is left untouched provides adequate shade to protect the water from high summertime temperatures. The old mature stand of trees provides natural reseeding and essentially, revegetation with desirable native species is probable.

Since the spoils are high in organic materials, seed germination and growth is quick, making bank stabilization less of a problem.

Certain wildlife species inhabiting the flood-plain are benefited by this method of right-of-way cutting, in that it provides secondary growth along with the natural mature stand on the opposite side of the stream.

Preliminary work on determining the effects on fisheries had yielded some interesting information. Game fish populations have been observed where none existed prior to stream clearance, with fishing access to the stream being greatly improved resulting in an increased utilization of the fishery, at least, by local residents.

It is anticipated that a more thorough study could result in finding that this process may actually be a method of stream restoration. One needs to look at the possibility that enhancement of fresh and salt water fisheries may be accomplished by opening up these small tributary streams for inland water game fishes and also the re-creation of spawning areas for some anadromous species is likely.

A list of fishes taken by a Wildlife Commission Fish Biologist can be obtained through the Solid Waste and Vector Control Branch, Department of Human Resources. The stream sampled (Back Swamp) had stream clearance work

done approximately three years previous to the sampling date. Most sections of the stream, prior to construction, were completely dry during the hot summer months. Water during the summer months, in the same sections, now range from two to eight feet in depth.

The desired drainage is accomplished using these modified methods of stream alteration. Drainage of the natural flood-plain is not intended, but getting excess water off of property that was not inundated prior to stream sediment build-up is the basic goal of these projects. This helps eliminate mosquito breeding areas, health related problems, economic, social, and welfare problems that may exist in areas that have drainage problems.

It is simply undoing what man, through his misuse of natural resources, has destroyed. Many of the small streams have been destroyed by improper logging practices of past years. The old stream-beds are filled with cut logs and tree tops, creating a blockage, which becomes silted in and over after a number of years. This causes complete elimination of the stream channel.

9. CONTROL BY CHEMICALS

9. CONTROL BY CHEMICALS

9.1 PESTICIDE SAFETY

Basically, there are three areas of particular safety concern: protecting the environment, avoiding undesirable residues in food and feed, and protecting the persons associated with the use and handling of pesticides.

1. Protecting the environment

We are part of a large and complicated system of living things interacting with each other and the physical factors of soil, air and water. This is usually referred to as our ecosystem.

Four basic basic problems must be considered in protecting our environment when using pesticides. The first is that the whole ecosystem is so complex that even a minor use at one place may have an unexpected and undesirable result at another. Second, because pesticides are poisons they may harm species other than intended target pests. Third, some pesticides move in the ecosystem to show up a long way from the point of application and some readily concentrate in animals. Fourth, some pesticides persist a long time.

The poisonous nature of a pesticide is measured as acute toxicity or chronic toxicity. Acute refers to a shorter term reaction to a single dose of the chemical while chronic toxicity refers to a longer term reaction to a continued dosage. Non-target animals can be injured or killed by both direct single dose acts and by slower long-term exposure. On land pesticides may first directly contact such things as beneficial insects and later move through the ecosystem to adversely affect fish and wildlife. Aquatic areas are especially sensitive and easily become contaminated. Pesticides often readily disperse in water and some

selectively build up in various living material. Particular care must be taken to assure proper selection, dosage and application of pesticides in aquatic environments. Most problems to date have involved the chlorinated hydrocarbon type insecticides such as DDT, sometimes referred to as hard or persistent.

II. Protecting food and feed

When pesticides are applied to crops and animals, it is important that farmers carefully follow label instructions. Particular attention must be paid to dosage, frequency of application and safe intervals to harvest. Raw agricultural commodities may have tolerances for certain chemicals. Routine sampling for excessive residues by regulatory agencies assures quality.

III. Protecting persons who work with pesticides

Although certain pesticides are safer to man than others, all pesticides are designed to kill something and should be regarded as poisons. Tests are performed to determine how poisonous (toxic) each pesticide is to standard test animals like rats and rabbits. These tests are helpful in determining how hazardous the pesticide might be to humans. It is important to distinguish between toxicity which is the natural characteristic of a substance to produce injury or death, and hazard which is a combination of toxicity and exposure. Hazard represents a potential threat that injury will result from the use of a substance in a given formulation or quantity.

An insecticide may be extremely toxic but present little hazard to the applicator or others when used in a very dilute mix or in a formulation which is not readily absorbed through the skin or readily inhaled

(granules). On the other hand, an insecticide may have a low toxicity to man but present a hazard because it is used in a concentrated form which may be readily absorbed or inhaled.

Labels of all pesticides today must indicate the relative toxicity and operator hazard by the EPA category and label warning words. The labels also give instructions on the proper type of protective clothing, mask or respirator, antidotes and first aid treatment. The following table, Oral, Dermal and Inhalation Ratings of Pesticide Groups is a useful guide.

Safety Instructions for Handling Pesticides

Wear clothing that covers the body and other protective devices such as gloves and respirators when recommended on the pesticide label. Never allow small children around pesticides.

Never eat, drink or smoke when handling pesticides. After using pesticides always wash before you eat, drink or smoke. Wash thoroughly anytime you spill or think you have come in contact with a pesticide.

Mix pesticide outside and downwind. Provide the proper light and ventilation while mixing. Take extra care in pouring pesticides and opening containers to avoid inhaling, splashing of liquids or contacting fumigant, liquid or dry pesticides. If you spill pesticides on your clothing, remove them immediately. If you spill pesticides, clean them up immediately.

Use common sense around pesticides. Treat them as poisons. Make sure your equipment is safe. Do not blow out clogged hoses with your mouth, and do not work in pesticide drift or runoff. Do not wash your hands in the spray mixture.

Oral, Dermal and Inhalation Ratings of Pesticide Groups

EPA Category-Meaning	Pesticide Label Warning*	Oral LD_{50} (mg/kg)	Dermal LD_{50} (mg/kg)	Inhalation LC_{50}** (µg/l)	Lethal Oral Dose for a 150 lb Man
I. Highly toxic	Danger Poison	0-50	0-200	0-2,000	few drops to teaspoonful
II. Moderately toxic	Warning	50-500	200-2,000	2,000-20,000	teaspoonful to one ounce
III. Slightly toxic	Caution	500-5,000	2,000-20,000	over 20,000	one ounce to one pint or pound
IV. Relatively non-toxic	Caution	over 5,000	over 20,000	---	over one pint or pound

*All pesticide labels carry a "Keep Out of Reach of Children" warning.

**Vapor or gas inhalation value may also be expressed in parts per million (ppm).

Do not leave pesticides unattended in the field or leave equipment partially filled at the end of the day. Clean up the equipment and put the pesticides in safe storage. Wash your clothing before wearing them again and take a good bath yourself.

How You Might Be Poisoned by a Pesticide

By mouth (oral)

Examples:
- Not washing hands before eating, smoking or chewing.
- Mistaking the pesticide as food or drink--especially children.
- By accidentally applying pesticides to food.
- Careless or accidental splash in the face.

By skin absorption (dermal)

Examples:
- By accidental splash or spray or spray on the skin with pesticide.
- By allowing pesticide contaminated (wet clothing) to touch the skin.
- By applying pesticides in drift conditions.
- By using pesticide contaminated clothing.

By nose - breathing vapors (inhalation)

Examples:
- By accidental contact with gaseous pesticides.
- By constant exposure to poisonous materials in closed spaces.
- By constant breathing of fumes from pesticides while applying them without protective equipment.
- By inhaling fumes immediately after applying a pesticide.

Storage of Pesticides

Always store pesticides in a secure dry place where humans (especially children), livestock and pets cannot come into contact with them. Children and animals are curious. They do not know the dangers of pesticides and they do not or cannot read the labels.

Always store pesticides in the original labeled container with the label plainly visible. Never store pesticides in soft drink or other bottles, or food containers that could be mistaken for food or drink for humans or animals.

Do not store pesticides near food or feed. Do not permit anyone to sleep, eat or play in a room where pesticides are stored. Do not allow food and drink dispensing machines in buildings used to store pesticides.

Always keep lids and bungs tightened when containers are not being used. Keep all "empty" pesticide containers in a locked storage area until disposed of properly. Follow the directions in the publication "Pesticide and Pesticide Container Disposal" in disposing of pesticides and pesticide containers.

Containers should be periodically checked for corrosion, leaks, breaks, tears, etc., so that damaged containers may be disposed of or replaced before they cause trouble.

Install an exhaust fan for ventilation in storage rooms to help reduce high concentrations of toxic fumes and to hold temperatures down. Locate these fans carefully so that the exhaust will not harm man or animals.

Pesticides requiring special storage will have warnings concerning proper storage on the label. Always read the label before storing a pesticide. Fire danger warnings should be obeyed.

Always keep pesticide storage places locked when not in use. Where large quantities of pesticides are stored fire resistant buildings, sprinkling systems and fire fighting equipment are strongly recommended. Fire departments, police departments and health officials should know about and inspect these storage areas at least once a year. Post a list of the chemicals and warning signs outside the building.

In emergencies such as fire or flooding, inform the officials dealing with the emergency of the types of pesticide stored in the building or area.

Pesticide Container Disposal

You have not finished your pesticide job until you have disposed of the container properly. Many "empty" containers are not empty. Children have been killed by drinking from, playing with or playing in "empty" pesticide containers. Practice this simple procedure to make sure containers are empty:

Rinse and drain procedure

(1) Empty container into the spray tank and let it drain, bottom up, for 30 seconds.

(2) Add rinse water until the container is one-fourth full.

(3) Rinse the container. Pour rinse into the tank and drain it for 30 seconds.

(4) Repeat this rinse and drain procedure three times.

(5) Crush the pesticide container immediately. Sell as scrap for recycling, or bury. Do not re-use.

The North Carolina Agricultural Extension Service is in the process of preparing a publication on Pesticide and Pesticide Container Disposal Obtain a copy of this bulletin and follow the directions in disposing of

pesticides and the specific pesticide containers (drums, cans, glass, paper, plastic, and other containers).

What is Medic Alert?

Medic Alert sponsored by the Medic Alert Foundation International is a non-profit, tax exempt organization dedicated to educating and encouraging people to wear identification of any medical problem that should be known in an emergency. Lifetime membership is $5.00 and includes a stainless steel medical identification neck dogtag or bracelet and a wallet card that describes your medical problem or hazardous occupation. The Medic Alert emergency phone number on the neck dogtag or bracelet can be called collect in an emergency to obtain medical information on file about the member.

Any person working with pesticides can join Medic Alert. Many physicians called in to treat an unconscious or severely poisoned victim may not know that the person has been poisoned with a pesticide or the treatment for the pesticide. A Medic Alert bracelet or neck dogtag giving information such as, "Exposed to organic phosphate" or "I am a crop duster" could save a life especially if the member's medical history and pesticide relationship were on file at the Medic Alert headquarters.

Membership applications for Medic Alert can be obtained from drugstores, physicians, Chambers of Commerce, and other places.

Medical Supervision for Pesticide Applicators

Persons handling or applying cholinesterase inhibiting pesticides such as carbamates and organophosphates may wish to be under medical supervision. Blood samples before handling these pesticides can establish

a person's normal plasma and red cell cholinesterase baseline value. Blood should be rechecked at intervals to see if the red cells and cholinesterase are normal. Rechecks should be made any time the worker becomes sick while working or within 12 hours of his last exposure to a cholinesterase inhibiting pesticides. If a person's plasma or red cell baseline values fall below normal, the applicator or handler should stop applying or handling pesticides until it returns to normal. Many commercial companies follow the above precautions with their chemists, biologists, and other employees that are constantly exposed to pesticides.

Poison Information - Poison Control Center

Duke University Hospital in Durham maintains a 24-hour consultant service in diagnosis and treatment of human illness resulting from toxic substances. Make sure that you and your physician know the Duke Poison Control Center's telephone number and do not hesitate to call in case of an emergency.

POISON CONTROL CENTER
Duke University Hospital
Box 3024
Durham, North Carolina 27701
Telephone: (Area Code 919) 684-8111

9.2 CHEMICALS AVAILABLE

The following 2 tables give information on the insecticides commonly used for mosquito control and related biting fly control.

The instructions on the label should be carefully studied and followed. There are many limitations and restrictions on the use of insecticides especially around aquatic habitats. The registered uses for chemicals changes and the latest information should be sought from reading the label and by contacting the Extension Service and other agencies.

Insecticides Commonly Used in Mosquito Control
(Adapted from CDC Public Health Pesticides Report 1973)

Type of application	Insecticides	Active ingredient per unit area	Treatment	Remarks
		Mg/sq ft		
Adult Residual Spray	malathion	100 or 200	Interior of buildings occupied by man or domestic animals.	Particularly persistent on wood surfaces where it remains effective for 3-5 months.
Adult Continuous Vapor Treatment	dichlorvos (Vapona)	1 dispenser/ 100 cu ft	Interior of buildings occupied by man or domestic animals.	Suspend dispenser from ceiling or roof supports. Active 2 1/2-3 1/2 months against adults. Do not use where infants, ill or aged persons are confined or in areas where food is prepared or served.
		1 dispenser/ catch basin	Catch basins in storm sewer systems.	Suspend dispenser 12" below catch basin cover.
		Lb/acre		
Adult Ground Space Treatments (mist or fogs)	carbaryl (Sevin)	0.2-1.0	Outdoors	Dosage based on estimated swath width of 300 ft. Apply as mist or fog from dusk to dawn. Mists usually dispersed at rates of 7-25 gal per hour at vehicle speed of 5 mph. Fogs are usually applied at rate of 40 gal/hr dispersed from vehicle at 5 mph. Finished formulations contain from 0.5-8 oz/gal actual insecticide in oil or in water (non-thermal) fog generator. Dusts also can be used (usually at 5%). For ground ULV application, technical grade malathion is
	fenthion[a] (Baytex)	0.00-0.1		
	malathion	0.075-0.2		
	naled (Dibrom)	0.02-0.1		
	pyrethrins (synergized)	0.002-0.0025		
	chlorpyrifos[a] (Dursban)	0.0125		

Insecticides Commonly Used in Mosquito Control (continued)

Type of application	Insecticides	Active ingredient per unit area	Treatment	Remarks
		lb/acre		
				dispersed at a rate of 1.0-1.5 fl oz/min and a vehicle speed of 5 mph, naled at 2-3 fl oz/min at 5 mph and pyrethrins at 2-2.25 fl oz/min at 5 mph. Adhere strictly to label recommendations. ULV sprays may damage finish of cars, planes or plastics.
Larval Ground or Aerial Treatments			Outdoors	Apply by ground or aerial equipment at rates up to 10 quarts of formulation per acre, depending upon concentration employed. Use oil or water emulsion formulations in areas with minimum vegetative cover. Where cover is heavy, use granular formulations.
	Abate	0.05-0.1		Harmless to non-target organisms. Can be used at 1 ppm (sand granules) in drinking water without harm to vertebrates.
	malathion	0.2-0.5		
	chlorpyrifos[ab] (Dursban)	0.0125-0.05		Highly effective in presence of organic matter.
	fenthion (Baytex)	0.02-0.1		
	Paris green	0.75		Apply in pelletized form (5%) at rate of 15 lbs/A. No resistance has yet been detected with this use. Apply to cover water in
	fuel oil[d]	2-20 gal/A		

Insecticides Commonly Used in Mosquito Control (continued)

Type of application	Insecticides	Active ingredient per unit area	Treatment	Remarks
				catch basins or at a rate of 15-20 gal/A on open water. With a spreading agent at rate of 0.5%, the volume can be reduced to 2-3 gal/A.

[a]For use by trained mosquito control personnel only.

[b]Not to be applied to waters containing fish, crabs or shrimp.

[c]Label requires a 3-week interval between applications except for fog treatments.

[d]Refined oils (e.g. Flit MLO) are available specifically for mosquito control.

Data on Mosquito Control Insecticides

Common name	Trade name	Acute toxicity LD^{50} mg/kg-rat oral	dermal	Origin	Type	Formulations	Remarks
Abate	Abate	13,000	>4,000	American Cyanamid 1965	OP insecticide with long residual activity	EC 4 lbs active/gal. Granules, 1, 10%. Dust 5%	
carbaryl	Sevin	500	>4,000	Union Carbide 1957	Carbamate contact and stomach poison with long residual effects	EC 13, 25%. Granules 5, 10% Dusts 5, 10% Aerosol 97.5%. WP 50,80%	Highly toxic to bees
dichlorvos	Vapona	56	75	Ciba 1955 Shell in U.S.	OP insecticide-acaricide, effective as a fumigant and a contact poison	23% impregnated resin strip	
chlorpyrifos	Dursban	82	202	Dow 1965	OP insecticide, effective as stomach and contact poison, and as a fumigant	WP, granules, EC	Toxic to fish
fenthion	Baytex	245	330	Bayer 1957 Chemagro in U. S.	OP insecticide-acaricide, long residual activity	EC 2,4 lbs active/gal. WP 25%. Dust 3%. Aerosols 1%	Toxic to bees
malathion	Cythion	1,000	>4,444	American Cyanamid 1950	OP insecticide-acaricide	WP 25, 50%, aerosols 1,2,4% EC 4,5, 10 lbs active/gal. Dust 4,5% granules 5,10%	

Data on Mosquito Control Insecticides (continued)

Common name	Trade name	Acute toxicity LD^{50} mg/kg-rat oral	Acute toxicity LD^{50} mg/kg-rat dermal	Origin	Type	Formulations	Remarks
naled	Dibrom	250	800	Chevron 1956	OP insecticide-acaricide, effective as a contact and stomach poison, with brief residual effects	EC 4,8,14 lbs active/gal. Dust 4%	Toxic to bees Does not apply at temp. over 90°F corrosive
paris green		100	2,400	1867	Inorganic copper and arsenical stomach poison insecticide	WP 90% Granules	Highly phyto-toxic
Propoxur	Baygon	86	2,400	Bayer Chemagro in U.S., 1963	Carbamate insecti-cide-acaricide, with contact and stomach activity	WP 50, 75%, EC 1.5 lbs active/ gal. Dusts 1/2, 1.5%. Granules 5, 10%. Bait 1,2%	Toxic to bees

9.3 ULTRA LOW VOLUME (ULV) INSECTICIDE APPLICATION

The use of ultra low volume (ULV) insecticides applied by ground equipment is rapidly replacing the use of thermal aerosol generators for adult mosquito control. There are several important factors which are influencing this conversion to ULV equipment. Several researchers have reported that control of adult mosquitoes using ULV insecticides were better than or at least equal to that obtained with the conventional thermal fogs when applied at equal dosages. Thermal fogs use the insecticide diluted in fuel oil (to 3-5% insecticide in the final mixture) and applied at 30-40 gallons per hour. Non-thermal aerosol ULV equipment uses the concentrated insecticide undiluted and applied at a few ounces per minute (1.5-2 gallons per hour). Very careful operation of the ULV equipment is necessary and the spray droplets must be in the correct range of sizes. The ULV offers the distinct advantages of no use of fuel oil with the resulting cost savings and no introduction of the oil into the environment.

A second major consideration on equipment is that of hazard to automobile and pedestrian traffic caused by the dense fog from thermal aerosols. The use of ground ULV equipment virtually eliminates this hazard. The insecticides are discharged from the ULV nozzle in an ultra fine mist which has little or no effect on visibility behind the moving vehicle.

To those involved in mosquito control, the ease of operation and costs are major considerations. The ULV non-thermal aerosol generators are of such weight and construction that compact vehicles may be used.

This great reduction in weight and materials required from that of the larger and heavier thermal aerosol generator units provide superior accessibility in most areas. Greater accessibility also offers increased aerosol coverage. Eliminating the bulk and weight inherent in thermal aerosol generators by using more compact equipment also reduces the limitations on driver visibility and therefore increases the drivers safety.

The operating cost including machines, vehicles, and materials of the thermal aerosol has been compared to that of the ULV non-thermal aerosol used by the Chatham County Mosquito Control Commission, Chatham County, Georgia. The operating cost for thermal aerosols were 15.6 cents per acre. The ULV non-thermal aerosol cost 4.1 cents per acre to operate, thus realizing a 73.7 percent per acre savings. They also reported fewer repairs and fewer truck nights lost due to inoperative vehicles or machines.

Installation of a LECO ULV-HD

The ULV non-thermal aerosol generator should be permanently affixed to the bed of a truck following the instructions accompanying your machine (Fig. 1 & 2). The truck should have flashing caution lights and "slow vehicle" warning signs. The can-rack unit holding the insecticide should be placed in such a manner that heat from the engine exhaust and motor block does not continually increase your insecticide temperature during mosquito control operations.

Placement of the remote control panel (Fig. 3) in the cab of the truck is very important. The panel must be placed so that the driver of the vehicle can easily see the controls and be within easy reach in order that adjustments may be made while the operation is in progress.

After permanently mounting the remote control panel, the electrical connections, insecticide line, and air hoses should be connected. Caution should be used when connecting the hoses to prevent leakage. The connections should be properly threaded and tightened only hand tight. Do not use a wrench.

Operating Engine

Be sure that the engine block is filled with oil. Fill the gasoline tank. With the insecticide tank empty, you should then check the operations of the engine unit. The correct engine speed is 2500 RPM. Check to see that all lines are tight and that pressure is building within the tank. By adjusting the engine throttle, the pressure gauge on the instrument panel should read 4 to 4½ PSI.

Filling Insecticide Tank

Stop the engine and remove the insecticide tank (or you may have an arrangement to pump the insecticide into the tank on the truck). Be sure not to spill insecticide on the bed of the truck. When handling and pouring the insecticide be sure to wear protective clothing (Fig. 4).

Calibration of Flowmeter

Before the unit is operational, it must be calibrated to deliver the desired flowrate per minute. The dosage recommendations will usually be given in terms of rate of flow and vehicle speed. Due to the number of different insecticides and variations in atmospheric

temperature at the time of dispersal, no specific flowmeter setting can be given for a particular rate of flow. It must be understood that, even for the same rate of flow, each insecticide requires a different flowmeter setting due to its specific gravity and viscosity. It must also be understood that for any one insecticide, no specific flowmeter setting can be given for a particular rate of flow due to the change in viscosity caused by temperature changes. Therefore, it is necessary to calibrate your flowmeter for your particular insecticide at the temperature at which it will be dispersed.

During calibration, the ULV generator should be placed in an isolated area. The vehicle should be facing into the wind so that the spray is blown away from you and your equipment. Be sure it is not blowing towards people, houses, animals, etc. Start the generator engine and again check the pressure gauge for a reading from 4 to 4½ PSI. Open the flowmeter needle valve all the way by turning it in a counter-clockwise direction. Turn the fog switch to ON. Allow the insecticide to flow through the system until all air bubbles disappear and then adjust the needle valve for the proper flow.

The proper flow rate for malathion ULV can be determined by the temperature correction curve (Fig. 5 & 6) furnished by Lowndes Engineering Company with the LECO ULV generator. Read the temperature from the temperature gauge on the instrument panel. Find this temperature on the correction curve. Then move straight up the page to the intersection of the temperature line with that of the plotted curve for the proper delivery rate. From that point or intersection, move across the page to the flowmeter scale to obtain the correct flowmeter setting. Adjust the flowmeter so that the center of the floating ball

is opposite the proper rate of flow. Note that the flowmeter is labelled with numbers which lock the zeros so that 12 on the flowmeter equals 120 and so forth. The flowmeter setting should be changed for every two degrees change in temperature.

To calibrate the flowmeter for the proper delivery rate, disconnect the insecticide line from the fogging head. With your flowmeter set to deliver a certain volume (3 oz. per min.), catch the insecticide in a calibrated container for several minutes. Calculate the flow per minute. If the flow rate differs from that on the chart, minor adjustments may be made by increasing or decreasing the pressure by adjustment of the engine throttle. An increase in pressure will increase the flow rate. It is extremely important to remember that the pressure should always be greater than 3½ PSI but never exceed 6 PSI. When the correct delivery rate has been obtained, turn the fog switch to OFF and reconnect the insecticide line back to the fogging head.

In most instances, you will not be using the exact dosage rate plotted and will therefore have to make your own curve to fit your desired dosage rates. Refer to temperature correction curve No. 2 (Fig. 6) for malathion. If, for example, you needed a flow rate of 4 oz. per min., read across the bottom of the graph labelled "flow" to 4. Then go directly up the line to where each of the temperature lines intersect the line above 4 and record each. You should get a flowmeter setting of 163 millimeter for $65^{o}F$, and 85 mm for $100^{o}F$. After having found the flowmeter reading for each fixed temperature between 65^{o}-$100^{o}F$, you then plot each point on graph No. 1. You then should connect each point forming a gradual curve (not a straight line

between points). After the free-hand curve has been drawn in, you may then read the flowmeter setting for any temperature between 65^{o}-100^{o}F.

Temperature-Flow Chart

Using the temperature correction curve for the insecticide and rate of flow that you will be using, a flow chart (Fig. 7 & 8) should be made to include the proper flowmeter reading for each temperature reading between 60^{o} and 100^{o}F. This flow chart should be attached to the instrument panel and be used to correct for temperature changes during operation. Remember that for each 2 degrees change in temperature, the flowmeter setting should also be changed.

Droplet Size Determination

The effectiveness of adulticides in mosquito control work depends on four factors:

1. the susceptibility of the mosquito to the insecticide being dispersed,
2. the dosage rate per unit area,
3. the droplet size and number of droplets per unit area, and
4. the exposure time of the mosquito.

The dosage rate is determined by the vehicle speed, the swath width, and the rate of insecticide flow. Doubling your vehicle speed, other factors remaining constant, will decrease your dosage rate by one-half. The droplet size is determined by the flowrate, pressure, and the nozzle size.

The droplet size is extremely important in ground adulticiding because heavier droplets tend to fall to the ground and droplets too small tend to drift up and away from the target mosquito. More than one-half of the total spray mass must consist of droplets in the 6 to 18 micron range. Four-fifths of the total spray mass must consist of droplets smaller than 24 microns. The mass median diameter of the droplets should not exceed 17 microns (that is, 50% of the spray volume is in larger than 17 micron droplets and 50% is in smaller than 17 micron droplets).

To obtain a perspective on the size of the droplets required, lets consider one gram of water. This one gram of water could be divided into:

30 rain drops measuring 4000 microns each,

30,000 spray droplets measuring 400 microns each,

30,000,000 aerosol droplets measuring 40 microns each,

30 billion medium aerosol droplets measuring 4 microns each.

The droplet size of your ULV non-thermal generator should be determined as frequently as necessary to insure proper droplet size. It must be determined before the machine is originally put into active use and following any mechanical changes or alterations. It should also be determined at regular intervals of approximately 50 operational hours. Label instructions for ULV chemicals specify the droplet size distribution required and these directions must be followed. Any equipment to be used for ULV application should be tested and demonstrated to be capable of producing the required droplet size distribution.

Droplet sizes are determined by depositing a sample of the aerosol onto a silicone coated glass slide and measuring the droplets under a high-power microscope. The slides may be prepared using silicone (General Electric SC-87 Dri-Film) or purchased ready for use.

A sample of the malathion aerosol is deposited on a slide by placing the slide onto the end of a 3 ft. stake and waving the slide through the aerosol cloud at a distance of 25 ft. from the point of discharge. The slides are waved perpendicular through the aerosol cloud and stored in a tightly sealed box for transfer to a location for counting.

Making Treatments

Your control district or County should be logically divided into several control areas. Each area should then be mapped with detail to include all roads and alley ways. The driver should familiarize himself with each area and plan his route of travel before leaving the control headquarters. An alternate route or routes should also be planned to account for wind direction. Do not drive with the wind blowing the insecticide into the cab of the truck or down wind of areas immediately treated. You should never drive into unfamiliar driveways before checking for obstacles or hazards. You do not apply insecticides while going into a driveway, roadway, or in any other manner that will necessitate driving back through the insecticide.

Before leaving your mosquito control headquarters, you should make a routine check on the vehicle and safety equipment (see equipment check list). Never assume that everything is operational today just because it worked correctly the last time out. Record pertinent

information, such as treatment area, date, operator, flow rate, vehicle speed, fogging time, and volume of insecticide in your tanks before the operation begins.

Do not operate the flashing amber lights in route to your assigned control area. After arriving at your area, you should note and record the time, wind direction, and approximate wind speed. Start your aerosol generator and check out all systems (refer to Operation of LECO ULV Generator). Operate your flashing amber lights and your emergency flashers. Turn the fog switch to on and adjust the flowmeter reading (refer to Flowmeter Temperature Chart). It is imperative that you maintain your assigned vehicle speed in order to deliver the proper dosage rate. When possible, drive at right angles to the wind. Cover all adjacent roads before moving to other parts of your area. By doing so, you will obtain better aerosol coverage and deliver a more lethal blow to the mosquito population.

When you have completed your assigned area, you should flush the insecticide from the machine by cutting the insecticide flow off and the solvent flow on. Flush the system for approximately two minutes and then turn the fog switch to off. Turn your generator engine off. Use a calibrated dip stick to measure the amount of insecticide in the container, record and calculate the total amount of insecticide used. Record the time that spraying operation was completed.

LIST OF FIGURES

Figure 1

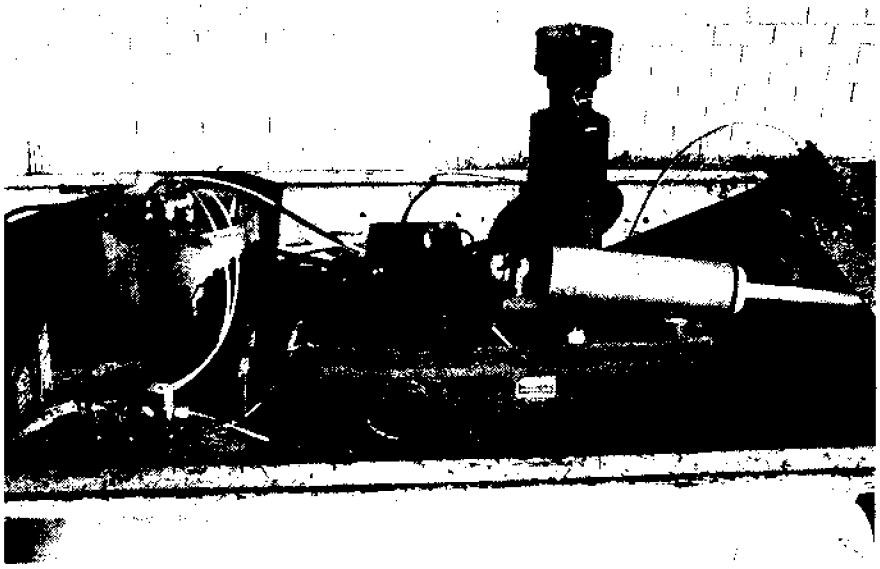


Figure 2

Figure 3

Figure 4

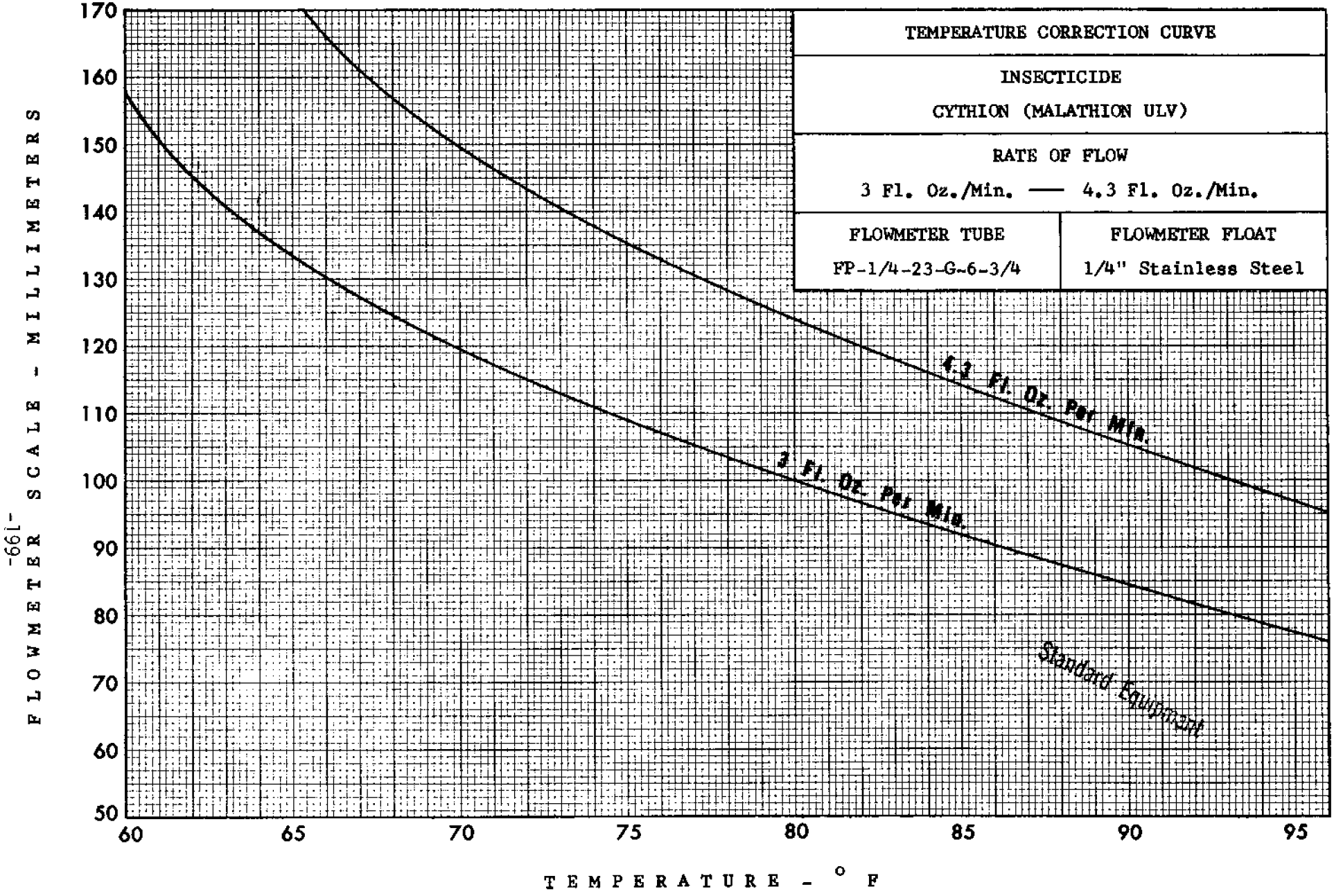
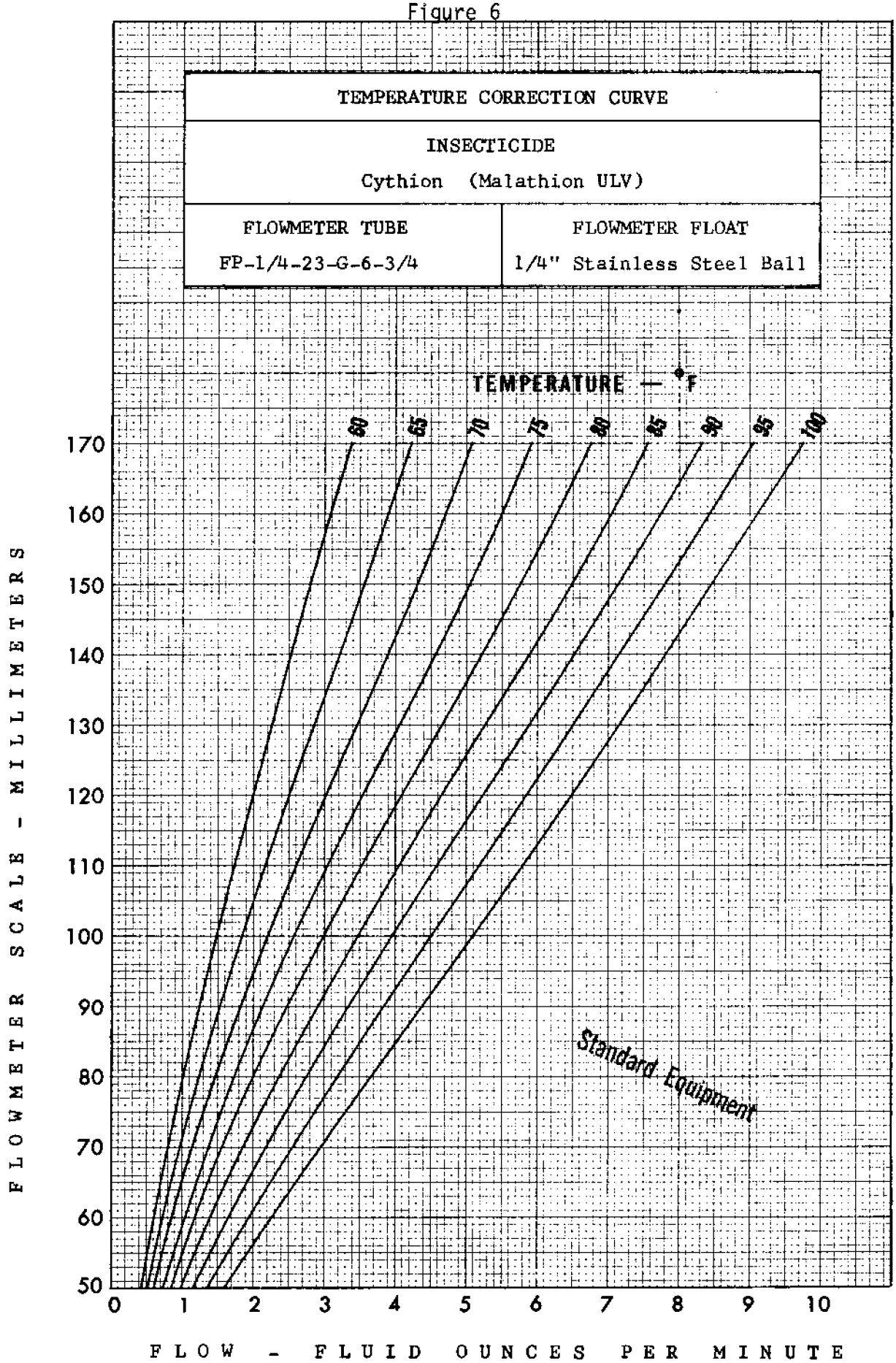

TEMPERATURE CORRECTION CURVE
INSECTICIDE
CYTHION (MALATHION ULV)
RATE OF FLOW
3 Fl. Oz./Min. —— 4.3 Fl. Oz./Min.
FLOWMETER TUBE
FP-1/4-23-G-6-3/4
FLOWMETER FLOAT
1/4" Stainless Steel
4.3 Fl. Oz. Per Min.
3 Fl. Oz. Per Min.
Standard Equipment
FLOWMETER SCALE - MILLIMETERS
170
160
150
140
130
120
110
100
90
80
70
60
50
60
65
70
75
80
85
90
95
TEMPERATURE - ° F

Figure 5

Figure 6


TEMPERATURE CORRECTION CURVE
INSECTICIDE
Cythion (Malathion ULV)
FLOWMETER TUBE
FP-1/4-23-G-6-3/4
FLOWMETER FLOAT
1/4" Stainless Steel Ball
TEMPERATURE — °F
60
65
70
75
80
85
90
95
100
Standard Equipment
FLOWMETER SCALE - MILLIMETERS
170
160
150
140
130
120
110
100
90
80
70
60
50
0
1
2
3
4
5
6
7
8
9
10
FLOW - FLUID OUNCES PER MINUTE

TEMPERATURE CORRECTION CHART

INSECTICIDE: Cythion (Malathion ULV)
RATE OF FLOW: 3 Fl. Oz./Min.
FLOWMETER TUBE: FP-1/4-23-G-6-3/4
FLOWMETER FLOAT: Stainless Steel

Temp. °F	Flowmeter scale	Temp. °F	Flowmeter scale
60	158	78	103½
61	150½	79	101½
62	145	80	100
63	141	81	98
64	137	82	96½
65	133½	83	95
66	130	84	93½
67	127	85	92
68	124½	86	90½
69	122	87	89
70	119½	88	87½
71	117	89	86
72	115	90	84½
73	113	91	83
74	111	92	81½
75	109	93	80
76	107	94	78½
77	105	95	77

Figure 7

TEMPERATURE CORRECTION CHART

INSECTICIDE: Cythion (Malathion ULV)
RATE OF FLOW: 4.3 Fl. Oz./Min.
FLOWMETER TUBE: FP-1/4-23-G-6-3/4
FLOWMETER FLOAT: Stainless Steel

Temp. °F	Flowmeter scale	Temp. °F	Flowmeter scale
60	*	78	128
61	*	79	126
62	*	80	124
63	*	81	122
64	*	82	120
65	*	83	118
66	166	84	116
67	161	85	114
68	157	86	112
69	153	87	110½
70	149½	88	108½
71	146½	89	107
72	143	90	105
73	140½	91	103½
74	138	92	102
75	135	93	100
76	133	94	98½
77	130½	95	97

*Off the flowmeter scale.

Figure 8

CHECK LISTS

a. If necessary to handle insecticide containers, hoses, or fittings, use protective clothing and gloves which are kept in cab of vehicle at all times. Gloves and clothing should be washed with soap and water thoroughly upon returning to office.

b. If insecticide comes in contact with skin during handling, wash area immediately with soap and cold water.

c. Flashing amber lights are to be operated only when actual operations are being conducted or when vehicle is stopped for repair. DO NOT operate lights when going to or returning from assigned area.

d. DO NOT drive with the wind blowing the insecticide into the cab of the truck or down wind of areas immediately treated.

e. DO NOT apply insecticide while going into a driveway, roadway, or in any other manner that will necessitate driving back through the insecticide.

f. NEVER drive into unknown side roads, back yards, driveways, lanes, etc., unless first checked as SAFE.

g. DO NOT leave insecticide "ON" while vehicle is not moving (except during equipment check at office).

h. Drivers must take showers and change clothing upon completion of operation.

i. Failure to comply with safety regulations should be grounds for dismissal.

BEFORE STARTING OPERATION

a. Inspect tires for proper inflation.

b. Check oil level on dip stick.

c. Check water in radiator.

d. Check battery water level and electrical connections.

e. Check fan belt.

f. Confirm presence of jack, lug wrench, first aid kit, and fire extinguisher.

g. Adjust seat and rear view mirrors to desired position.

h. Check brake petal (height and resistance).

i. Check gas level in vehicle.

j. Check oil level in engine of spray equipment.

k. Check gas level of engine.

l. Check blower nozzle position.

m. Check insecticide and solvent containers.

n. Using dip stick, measure amount of insecticide in containers before start of operation and record.

o. Confirm presence of detailed maps of treatment areas.

p. Confirm presence of flow chart for your particular insecticide and your temperature range.

OPERATION OF VEHICLE

a. After engine has been started--check all gauges or warning lights.

b. Check brake lights, turn indicators, and head lights.

c. Fasten safety belts.

d. Observe all gauges at periodic intervals during operation.

e. If any vital or safety system does not function properly, do not drive, and report immediately to supervisor.

f. Observe all traffic rules.

g. Maintain vehicle at assigned speed at all times during actual operations.

h. Operate flashing amber lights at all times during actual operation.

OPERATION OF LECO ULV MACHINE

a. Attach flow rate chart for desired output to instrument panel.

b. Start Briggs and Stratton engine.

c. Check pressure gauge (not less than 4 psi, and not greater than 6 psi). Adjust accordingly using throttle of engine.

d. Begin operation by turning switch to "ON" position.

e. Check chart on instrument panel and make necessary adjustment to flowmeter to meet temperature changes.

f. Check insecticide temperature gauge at least once every 5 minutes and make adjustments and make adjustments for every 2 degrees of temperature change.

CONCLUDING OPERATIONS

a. Flush insecticide from machine by cutting insecticide flow off and solvent flow on; let run for a couple of minutes then turn switch off.

b. Shut Briggs and Stratton engine off.

c. Using dip stick, measure amount of insecticide in containers after completion of operation. Calculate total amount of output.

d. Record the time of the fogging timer and calculate the total time the aerosol generator was operational.

PARKING VEHICLE

a. Park vehicle in an assigned location.

b. Remove all unassigned equipment and waste from vehicle.

c. All switches should be in "OFF" position.

d. Close windows.

e. Report all needed vehicle maintenance or repairs to supervisor.

TRAFFIC

a. YIELD TO ALL TRAFFIC, vehicular or pedestrian, approaching from any direction.

b. Observe vehicles approaching from the rear. If their speed seems excessive, pull over to shoulder of the road.

c. If traffic build-ups occur, pull over on shoulder of road and stop.

d. Application should NOT be conducted on main traffic arteries, streets, or roads where high speeds are permitted.

e. Never conduct application ACROSS main traffic arteries.

f. Never drive against traffic.

g. Treat coming out of dead-end streets or drives--NOT going in.

MISCELLANEOUS

a. Riders other than mosquito control personnel are not allowed. NO EXCEPTIONS.

b. In case of an accident, notify the Police and your supervisor immediately.

c. Report all note-worthy problems or events to your supervisor following each assignment.

WIND

a. ULV application should be conducted at right angles to the wind, if at all possible.

b. Wind direction may change several times during the night. Therefore, the driver should constantly observe wind direction and adjust accordingly.

c. ULV application should NOT be conducted in winds in excess of 10 MILES PER HOUR.

TEMPERATURE AND RAIN

a. ULV work should not be conducted during daylight hours, except under special conditions.

b. Insecticide temperature should be checked frequently (at least every 5 minutes), and the flowmeter adjusted accordingly. Follow temperature flowrate chart attached to instrument panel.

c. ULV application should not be carried out in HEAVY rain. Light showers are permissible.

d. Engine should be covered during heavy rain to prevent drown-outs.

a. After each usage the entire system must be flushed out. Flushing can be done simply by removing the manifold cap from the insecticide can and inserting the drop tube into a container of solvent. Start the fogger and let it run for several minutes to be sure that all the insecticide is flushed out. Iso-propyl alcohol or naptha should be used as a flushing agent.

   An alternate to this system is to install a three-way valve into the insecticide line. One tube runs to a permanently mounted solvent container and the other to the insecticide. The third line goes to the flowmeter. Flushing can then be accomplished simply by turning the three-way valve so that the solvent runs through the system instead of the insecticide.

b. Refill the insecticide container.

c. Refill the solvent container.

d. Refill the gasoline tank to the generator engine.

e. Check all hoses and lines for leakage or wear.

WEEKLY MAINTENANCE

a. Check the belts and adjust if necessary. The proper adjustment is 3/4 inch deflection midway between the pulleys.

b. Check the engine speed and reset if necessary to obtain proper pressure in the system.

c. Check all bolts and fasteners and tighten if necessary.

d. Remove and clean the screen on the air intake silencer. Before replacing the screen, start the engine and while holding the throttle at idling speed, pour 1/8 pint of lubricating oil in the air intake. This will prevent a coat of rust from forming inside the blower.

e. Check the oil in the engine and change at given intervals. The oil drain plug on the LECO engine creates a problem when draining the oil. A large plastic bag makes an excellent catch container for the oil.

f. Check the points and plugs for proper setting and corrosion. Replace if necessary.

REGISTRATIONS FOR INSECTICIDES FOR ULTRA LOW VOLUME NON-THERMAL GROUND APPLICATION FOR ADULT MOSQUITO CONTROL

NOTE: Label registrations change and the latest information should be obtained. Always READ THE LABEL and follow the INSTRUCTIONS AND RESTRICTIONS. This list was prepared 1 April 1974 (R. C. Axtell). The rates given below are for a 300 ft. swath width which can be used to calculate amounts per acre.

1. Malathion: American Cyanamid Co.

   Trade names: CYTHION, MALATHION ULV CONCENTRATE

   Formulation: 95% actual malathion; 1 gallon contains 9.7 lbs. malathion

   Rates: 1.0 to 2.1 fld. oz./minute at 5 mph, 2-6 psi.
   2.0 to 4.3 fld. oz./minute at 10 mph, 2-6 psi.
   See label for droplet size requirements.

   EPA Reg. No. 241-208-AA

2. Pyrethrin: MGK Corp.

   Trade names: PYROCIDE CONCENTRATE, PYROCIDE FOGGING FORMULA 7067

   Formulation: Concentrate contains 12% pyrethrin and 60% piperonyl butoxide (synergist). Formula 7067 contains 5% pyrethrins and 15% piperonyl butoxide.

   Rates: Concentrate is to be diluted 1 to 1.4 (by weight) to make a 5% pyrethrin material. Formula 7067 is used without dilution. Rates for 5% pyrethrin plus synergist are:

   2 to 2.25 fld. oz./minute at 5 mph, 3 psi.
   4 to 4.5 fld. oz./minute at 10 mph, 3 psi.

   EPA Reg. No. 1021-1185

3. Naled: Chevron Chemical Co.

Trade name: DIBROM 14 Concentrate

Formulation: 85% actual naled; 1 gallon contains 14 lbs naled

Rates: Concentrate is to be diluted 2 qts. in soybean oil or HAN to make 5 gallons of dilute solution. Apply dilute material at following rates:

3 to 6 fld. oz./minute at 5 mph, 1.5 psi.

6 to 12 fld. oz./minute at 10 mph, 1.5 psi.

See label for droplet size requirements. Mix immediately before use, do not store diluted.

EPA Reg. No. 239-1721-AA

Trade name: DIBROM ULV Insecticide (Summit Chemical Co.)

Formulation: A prepared dilution of naled containing 15% actual naled by weight. Ready to use.

Rates: 6 fld. oz./minute at 5 mph, 1.5 psi.

12 fld. oz./minute at 10 mph, 1.5 psi.

EPA Reg. No. 6218-40

4. Chlorpyrifos: Dow Chemical Co.

Trade names: DURSBAN, Dow Mosquito Fogging Concentrate

Formulations: 61.5% actual chlorpyrifos; 1 gallon contains 6 lbs. chlorpyrifos

Rates: 2/3 to 1 1/3 fld. oz./minute at 10 mph, psi not specified.

See label for droplet size requirements.

EPA Reg. No. 464-428

10. LAWS AND REGULATIONS

10. LAWS AND REGULATIONS

10.1 PESTICIDE LAWS

There are two primary pesticide laws of concern to persons in public health pest control. These are the N. C. Pesticide Law of 1971 and The Federal Environmental Pesticide Control Act of 1972 (Public Law 92-516). A brief explanation of these bills is given here. Also included here is a discussion of other federal agencies regulating pesticides.

North Carolina Pesticide Law of 1971

On July 12 the North Carolina General Assembly enacted the "North Carolina Pesticide Law of 1971". As stated in its full title this law is "An Act to provide for the protection of the quality of the environment and for the protection of the public health through regulation of the use, application, sale and disposal of pesticides and the registration of pesticides." This legislation does provide for regulation of use, sale, storage, disposal and application of all pesticides and repeals the "North Carolina Insecticide, Fungicide and Rodenticide Act of 1947" (GS ARticle 4 A, Chapter 106) and the "North Carolina Aerial Crop-Dusting Law" (GS Article 4 B, Chapter 106) effective October 1, 1971.

Some of the more significant provisions of this law are as outlined below.

Pesticide Board

The Pesticide Board is responsible with the Commissioner of Agriculture to carry out the provisions of the Act. The Board is to be appointed by the Governor and shall consist of seven members as follows:

(1) A representative of the North Carolina Department of Agriculture.

(2) A representative of the North Carolina Board of Health.

(3) A representative of a state conservation agency.

(4) A representative of the agricultural chemical industry.

(5) A person engaged in agricultural production.

(6) A citizen at large who is a non-institutional conservationist.

(7) A citizen at large not associated with agricultural production or the chemical industry.

This Board may adopt regulations and set policy following one or more public hearings with four concurring votes from its membership.

The Commissioner of Agriculture is charged to enforce and administer the law.

Powers of the Pesticide Board

The Pesticide Board is authorized to:

(1) Appoint a "Pesticide Advisory Committee" to assist the Board and the Commissioner in an advisory capacity.

(2) Adopt and revise a list of restricted use pesticides if in the judgement of the Board such action is necessary. The restriction may include the time and condition of sale, distribution or use; may include prohibition of use for designated purposes; may require the purchaser to certify use as labeled; or may require a use permit issued by the Board.

(3) Adopt regulations concerning handling, transport, storage, display and disposal of pesticide wastes as well as restricting or prohibiting certain types of packages and containers which may apply to their strength and/or size to alleviate danger of spillage, breakage or misuse.

(4) Register all brands or grades of pesticides prior to sale or an offer to sell for an annual fee of $25.00.

(5) Suspend registration immediately to prevent an imminent hazard to the public or to a nontarget organism or segment of the environment.

Dealers and Manufacturers

All persons in the business of distributing, selling, offering for sale or holding for sale restricted use pesticides are to be licensed by January 1, 1972 for each outlet or location for an annual fee of $25.00. Minimum qualifications for an applicant for a license include two years of experience or suitable education or a college degree in lieu of experience.

A written and/or oral examination prescribed by the Board must be satisfactorily completed prior to January 1, 1974 and renewal examinations shall be prescribed by the Board at intervals of not less than four years.

Names of employees of dealers must be submitted to the Board at each renewal or upon request of the Board and each dealer is responsible for the actions of his employees.

Revocation of dealers license: the Board may revoke a license for violation of the act by licensee or employee of a licensee for not more than two years.

Applicators and Consultants

Any person who owns or manages a pesticide application business who applies pesticides on lands of another except persons who apply pesticides on their own land with ground machine or for the accomodation of his neighbors or is licensed under the North Carolina Structural Pest Control Act must be licensed by January 1, 1972 for an annual fee of $25.00.

Each piece of terrestrial equipment is to be licensed; the fee is $10.00. Each piece of aerial equipment is to be licensed; this fee is $25.00.

Qualifications for an applicant for an applicators license include two years experience or suitable education or a college degree in lieu of experience.

A written and/or oral examination prescribed by the Board must be satisfactorily completed prior to January 1, 1974 and renewal examinations shall be prescribed by the Board at intervals of not less than four years.

The names of all solicitors, salesmen and operators must be furnished to the Board at each renewal or upon request of the Board and applicators are responsible for the actions of their employees.

Revocations of Applicator's License: Provision is made for revocation of licenses by the Board for not more than two years for violation of the act by the applicator or his employees.

Reporting Volumes of Pesticides

Persons selling pesticides to the consumer shall report to the Board all purchases, sales and shipments of restricted use pesticides and any other pesticides designated by the Board.

Inspection

The Board may for purposes of enforcing the act may inspect all equipment and premises subject to the act, inspect lands on which pesticides are used, inspect storage and disposal areas, inspect complaints of injury to humans, lands or plants and sample pesticides being applied or to be applied.

Interim Licenses

The Board is authorized to issue provisional or interim licenses to all categories of licensees or to waive particular requirements or to provide for phasing of license requirements but no interim or provisional license shall be valid later than December 31, 1973.

Federal Environmental Pesticide Control Act of 1972

The new Act completely revises the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) which has been the basic authority for Federal pesticide regulation since 1947.

The law prior to the new legislation prohibited interstate commerce of unregistered pesticides, and permitted registration only when, if used as directed or in accordance with commonly recognized practice, the pesticide would not be injurious to man, vertebrate animals, or desirable vegetation. It did not prohibit the misuse of any registered pesticide, nor did it regulate pesticides that moved only in intrastate commerce.

The new Act regulates the use of pesticides to protect man and the environment and extends Federal pesticide regulation to all pesticides including those distributed or used within a single State.

Major provisions of the new Act will:

-- prohibit the use of any pesticide inconsistent with its labeling. No pesticide may be registered or sold unless its labeling is such as to prevent any injury to man or any unreasonable adverse effects on environmental values, taking into account the public interest, including benefits from its use.

-- require pesticides to be classified for general use or restricted use. Restricted use pesticides may be used only by or under the supervision

of certified applicators or subject to such other restrictions as the administrator of EPA may determine.

-- strengthen enforcement by: requiring the registration of all pesticide producing establishments; authorizing entry of establishments and other places where pesticides are held for sale or distribution for inspection and obtaining samples; authorizing stop sale, use, or removal orders and seizure against hazardous pesticides if necessary.

-- authorize the payment of indemnities to persons holding pesticides before the issuance of a suspension notice if the pesticide is finally cancelled; except a manufacturer may not receive any indemnity if he had knowledge of facts that the pesticide should be suspended or cancelled and does not advise the Administrator.

-- authorize the Administrator to establish pesticide packaging standards, regulate pesticide and container disposal; issue experimental use permits, conduct research on pesticides and alternatives and monitor pesticide use and presence in the environment.

-- provide for certification of pesticide applicators by the States under a program approved by the Administrator; for cooperative enforcement with States; grants-in-aid and other assistance to States. States are also authorized to issue conditional registrations for pesticides intended for local use, and could impose greater regulation on a pesticide than that of the Federal government, except as to packaging and labeling.

-- establish a series of effective dates for various provisions of the Act and continue the existing law in effect until the new provisions become effective. Every provision of the new Act must be effective within four years.

Other Federal Agencies Regulating Pesticides

The Federal Insecticide, Fungicide and Rodenticide Act of 1947 placed the burden of proof of acceptibility of a product on the manufacturer prior to its being marketed. The Act was intended to protect the user, the consumer and the public from pesticides, many of which are dangerous and all of which are subject to limitations in application. In 1948, the Food and Drug Administration began establishing safe tolerance levels of residues in foods. In no case were tolerances established that exceeded a safety factor of 100 to 1. In addition to this safety factor, tolerances were never approved for levels higher than necessary to accomodate registered users. The new 1972 Federal Environmental Pesticide Control Act replaces the FIFRA Act of 1947. In 1954, the Miller Amendment to Food and Drug laws formalized the tolerance setting procedures of FDA and as a matter of policy USDA registered only pesticide uses which would result in no residues or residue levels declared safe by FDA. The pesticide industry was required to submit to USDA data providing the efficacy of the chemical to control the pest and to submit to FDA proof of the safety of any measurable residues in the food produced. The Delaney Clause prohibits any residue of carcinogenic (cancer producing) chemicals.

The Environmental Protection Agency, created December 2, 1970, is now responsible for the pesticide regulatory functions previously delegated to the Departments of Agriculture; Health, Education and Welfare; and Interior. These responsibilities include the registration of pesticides as required under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA); the setting of tolerances, as required by the Miller Amendment to the Federal Food, Drug and Cosmetic Act; and many of the research and monitoring programs relating to pesticides previously conducted by the

three departments. In addition, EPA assumed the functions of the Federal Water Quality Administration (formerly under the Department of the Interior; the National Air Pollution Control Administration (formerly under HEW); and nuclear radiation controls (formerly under the Atomic Energy Commission).

The Food and Drug Administration still retains the responsibility to monitor food for humans and feed for animals. Any products violating pesticide residue tolerances are subject to seizure by FDA. The Federal Food, Drug and Cosmetic Act delegates this authority.

The Federal Aviation Administration under the Federal Aviation Regulation, Part 137--Agricultural Aircraft Operations, January 1, 1966, regulates the dispersing of pesticides by aircraft. Under these regulations as amended it is a violation for an aerial applicator to apply any pesticide except according to federally registered use. In Washington, there is close cooperation between the Department of Agriculture and FAA. The Department depends on FAA to determine the flying ability of agricultural pilots and the airworthiness of their aircraft. FAA personnel rely on the Department to test aerial applicators regarding their knowledge of pesticides and to investigate pesticide complaints.

The United States Department of Agriculture, Consumer and Marketing Services, Meat and Poultry Insection Program monitors the quality of meat and poultry products. Sampling is scheduled on a national basis through the use of a computer. Samples are identified as to source. Questionable samples are followed up with inspections at the product's origin where appropriate action is taken to prevent the marketing of contaminated meat.

Other State and Federal Laws

Federal Migratory Bird Act

Migratory birds that move from place to place (cross state lines) are protected by the Federal Migratory Bird Act. All migratory non-game birds, for example the robin and bluebird, are fully protected. The Federal Government sets the bag limits and hunting seasons for migratory game birds, for example, doves, woodcocks and water fowl. Fines can be imposed for violators of this Act.

State Game and Fish Laws

The Game and Fish Laws of North Carolina are designed to protect non-game species and to regulate the harvest of game species. The law prohibits the use of poisons to control wild birds and animals. Fines can be imposed for violators of these laws.

State and Federal Water Laws

State and Federal laws prohibit using or disposing of any pesticide or pesticide container in such a manner that would pollute any water supply or waterway. State laws permit the state to recover with fines the cost of any fish or wildlife killed by water pollution and the cost of investigation into these matters.

Control of Bird, Rodent and Fish Pests

Suggestions for the control of animal pests can be found in the current North Carolina Agricultural Chemicals Manual. These suggestions depending on the animal include trapping, shooting, cleaning up debris, trash, etc., and pest proofing buildings. The use of pesticides to control animal pests in North Carolina is illegal.

10.2 STATE REGULATIONS AND REPORTS

Most states have laws and regulations in regards to mosquito and related pest control. Mosquito control districts may be organized in North Carolina under the provisions of Article 24, Chapter 130 of the N. C. Public Health Statutes. This provides the mechanisms for organizing and funding control work on a local basis.

Also, State funds are appropriated for assisting localities in their mosquito control efforts. These funds are administered by the Division of Health Services which through its Solid Waste and Vector Control Branch provides certain guidelines, rules and regulations which must be followed in order to obtain the State funds. These are included on the following pages of this section.

In order to use chemicals in a control program, two principles should be kept in mind: (1) Only chemicals registered for the particular use in North Carolina may be used. Registration is a function of the North Carolina Department of Agriculture. (2) State matching funds are authorized only for those chemicals which are approved by the North Carolina Division of Health Services. Up-to-date information is available from the Solid Waste and Vector Control Branch. Prior approval for purchase of chemicals and equipment is the appropriate procedure to assure eligibility of the locality for matching State funds.

NORTH CAROLINA STATE BOARD OF HEALTH
RULES AND REGULATIONS GOVERNING STATE AID TO MOSQUITO CONTROL DISTRICTS OR OTHER LOCAL GOVERNMENTAL UNITS ENGAGED IN MOSQUITO CONTROL UNDERTAKINGS.

For the purpose of administering State funds received by the State Board of Health to aid mosquito control districts or other local governmental units engaged in mosquito control undertakings, pursuant to the provisions of Chapter 832, Session Laws of 1957, the North Carolina State Board of Health adopts the following Rules and Regulations Governing State Aid To Mosquito Control Districts Or Other Local Governmental Units Engaged In Mosquito Control Undertakings.

SECTION I. CREATION OF ZONES

For the purpose of administering these rules and regulations, the State of North Carolina is divided into three zones as follows:

A. Zone I shall be comprised of those counties in which the studies of the Salt Marsh Mosquito Study Commission showed a salt marsh mosquito problem to exist, and shall include the following counties: Beaufort, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Hyde, Jones, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell, and Washington.

B. Zone II shall be comprised of those counties not in Zone I where the highest probability of mosquito-borne disease outbreaks exists, and shall include the following counties: Gates, Hertford, Bertie, Martin, Pitt, Lenoir, Duplin, Sampson, Bladen, Columbus, Robeson, Cumberland, Johnston, Wayne, Greene, Wilson, Nash, Edgecombe, Halifax, and Northampton.

C. Zone III shall be comprised of those counties not included in Zone I or Zone II.

SECTION II. ALLOCATION OF STATE FUNDS OR FACILITIES - GENERAL

Before aid is given in the form of cash, the county, town, or other governmental unit applying for such aid shall submit a project application to the North Carolina State Board of Health on a form provided for that purpose.

Project applications shall list the cash, materials and supplies, equipment, and other facilities that will be provided by the applicant during the fiscal year.

In computing the monetary value of local funds and facilities provided by the applicant, in order to determine the amount of State aid that can be given on a matching basis, credit will be allowed for labor, materials, and general operating expenses, as well as rental on equipment that has been approved for use on the project by the representative of the State Health Director. The rental rates will be established by said representative of the State Health Director. No credit will be allowed for money spent to repay loans or to pay interest, purchase equipment or real estate, nor for overhead expenses such as office and storage space, rental, etc.

State funds shall not be spent by local governmental units to purchase equipment, make repayments on loans, pay interest on borrowed money, purchase real estate, rent storage or office space, nor for any purposes other than those directly connected with the application of mosquito control operations.

Embodied in project applications shall be such assurances and agreements as may be required by the official of the North Carolina State Board of Health who is responsible for the administration of this activity. These shall include:

(a) The assumption by the applicant of such responsibility for claims for damage resulting from the operation of the project as is necessary to absolve the State or any of its departments or agencies from any liability whatsoever from such claims.

(b) An agreement to submit such plans as may be required to the North Carolina State Board of Health, and to perform all work in conformity with the plans that are approved by the appropriate representative of the North Carolina State Board of Health.

(c) An agreement to use funds provided by the North Carolina State Board of Health and those shown on the project application as being provided by the applicant exclusively for mosquito control, in accordance with these rules and regulations and the approved plan.

(d) An agreement to perform all mosquito control under the direction of a competent supervisor who shall be approved by the designated representative of the North Carolina State Board of Health.

(e) An agreement to submit reports at the end of each month showing work performed during the month, expenditures made, facilities utilized, and materials expended.

(f) An agreement to submit a certified financial statement to the North Carolina State Board of Health no later than ten days after the last day of December and June of each year. Such statement must include an itemized account of expenditures during the preceding six months, of both local and State funds, as well as an itemized account of other assets and facilities that have been utilized to carry out the mosquito control project. Such supporting documents as may be required by the North Carolina State Board of Health shall be included.

(g) An agreement to return to the North Carolina State Board of Health, at the end of December and June of each year, all State funds not matched by local expenditures for mosquito control purposes during the preceding six months. In lieu thereof, the State Health Director may allow the excess of State funds, over local funds expended during the preceding six-months period, to be deducted from the State aid given the applicant during the next six-months' period.

In Zone I, if the application for State aid is made by a county, the application must be signed by the local Health Director, and the project must be operated under his direction, or under a person designated by him. If the application is made by a local governmental unit other than a county, a resolution must be adopted by the governing board of such governmental unit designating an official to sign necessary papers in connection with the mosquito control project. In such cases, operation of the project shall be under the direction of the designated official, but approval of the project by the local Health Director shall be required. In Zones II and III, the project application shall be signed by the local Health Director, and the project shall be carried out under his direction,

or under a person designated by him.

The provisions of these regulations requiring that the local Health Director sign, approve, or direct a project shall not apply to any application made by, or project conducted by a Mosquito Control District established under the provisions of Chapter 1247, 1957 Session Laws.

SECTION III. ALLOCATION OF FUNDS

A. The following rules and regulations shall apply to the allocation of funds for major drainage, diking and filling:

(1) The amounts provided by local appropriations, or the monetary value of other facilities provided locally, for drainage, filling, or diking, shall be matched with State funds on the basis of twice the local appropriation, or the monetary value of other facilities provided locally. In computing the monetary value of facilities provided locally, the total rental credits for draglines shall not be allowed, unless the draglines excavated an average of forty cubic yards of earth per hour, except when the work is being done under conditions where it is not possible to average forty cubic yards per hour. When the average is less, the total hourly rental credit for draglines for any month may be determined by dividing the cubic yards of earth excavated with draglines during the month by forty.

(2) No State funds shall be paid on a matching basis for drainage, filling, or diking unless the work has been performed in accordance with the directions of a representative of the North Carolina State Board of Health. Payment shall not be made for work performed during any month until a report has been received from the local governmental unit, with supporting documents required by the North Carolina State Board of Health showing work performed, expenditures made, and facilities utilized, except that an advance payment of one thousand four hundred dollars ($1,400.00) may be made for each dragline operated on the project, pending the availability of local funds that have been appropriated. The amount of such advance payments shall be deducted from subsequent State funds that are due on a matching basis later in the fiscal year.

B. The following rules and regulations shall apply to the allocation of funds for mosquito control other than major drainage, diking and filling:

(1) Zone I. If sufficient State funds are available, the amounts provided by local appropriations for mosquito control projects in Zone I shall be matched on a fifty-fifty basis for temporary control measures, and on a basis of twice the amount of local appropriations, or the monetary value of other facilities provided locally, for drainage, filling, or diking. If insufficient State funds are available for matching on this basis, the State aid is to be allocated to local projects in any one county as follows: the first one thousand dollars ($1,000.00) of State aid is to be on a fifty-fifty basis; thereafter, the State aid is to be allocated on a pro rata basis to be determined by dividing the total remaining appropriations and monetary value of other facilities provided (above the one thousand dollars ($1,000.00) matched on a fifty-fifty basis) by all of the local governmental units in Zone I into the total remaining State aid available for projects in that zone. In no case is the State aid to all projects within a county to exceed fifteen thousand dollars ($15,000.00) when there are insufficient funds to match on a fifty-fifty basis.

Two or more governmental units in Zone I may jointly employ a supervisor to look after mosquito control activities. The North Carolina State Board of Health may match local funds to pay the travel and salary of such supervisors on a fifty-fifty basis, if State funds are available. The qualifications of supervisors employed under this provision must be approved by the representative of the State Health Director.

(2) Zone II. The local Health Director shall be the official in Zone II who is recognized by the North Carolina State Board of Health as authorized and empowered to sign and execute documents necessary in connection with applications for aid in the control of mosquitoes, to carry out all agreements stipulated in the project applications, and perform other acts that are necessary in connection with the operation of the project.

All State funds and other facilities provided for mosquito control projects in Zone II shall be disbursed through the local Health Director.

In Zone II, State funds allotted to local health departments for mosquito control purposes shall be allocated on a fifty-fifty basis with local funds, or the monetary value of other facilities provided locally, with a maximum allocation of three thousand dollars ($3,000.00) to any local health department.

(3) Zone III. The local Health Director shall be the official in Zone III who is recognized by the State Board of Health as authorized and empowered to sign and execute documents necessary in connection with applications for aid in the control of mosquitoes, to carry out all agreements stipulated in the project applications, and perform other acts that are necessary in connection with the operation of the project.

All State funds and facilities provided for mosquito control projects in Zone III shall be disbursed through the local Health Director.

In Zone III, State funds allotted to local health departments for mosquito control purposes shall be allocated on a fifty-fifty basis with local funds, with a maximum allocation of one thousand dollars ($1,000.00) to any local health department.

SECTION IV. AUTHORIZED CHANGES IN ALLOCATION RULES

If at the end of a reasonable deadline for submission of applications for State funds to aid in mosquito control in any zone the funds set aside for aid in that zone have not been applied for, and allocated to local governmental units in that zone, the State Health Director is authorized to utilize such funds for assistance to projects in other zones, and to change the allocation basis.

If at the end of the second quarter of the fiscal year it is determined by the official of the North Carolina State Board of Health, who is responsible for the administration of this activity, that State funds allocated to any project will probably not be spent and matched by local expenditures, or other creditable assets by the end of the fiscal year, said funds may be re-allocated to other

local projects on the basis of potential mosquito densities and local participation.

Other State funds that become available for allocation to local projects from any source, after the end of the second quarter of the fiscal year, may be allocated to local projects in either of the three zones on the basis of potential mosquito densities and local participation.

SECTION V. REPEAL

All rules and regulations heretofore adopted by the North Carolina State Board of Health in conflict with the provisions of these rules and regulations are hereby repealed. The regulations concerning State aid to local governmental units for mosquito control purposes, adopted by the North Carolina State Board of Health on July 16, 1959, and amended on September 29, 1961, and January 9, 1964, are hereby repealed, and replaced by these rules and regulations.

SECTION VI. EFFECTIVE DATE

These rules and regulations shall be in full force and effect from and after September 19, 1968.

The foregoing rules and regulations relating to the administering of State aid to assist local governmental units in carrying out mosquito control projects were duly adopted by the executive committee of the State Board of Health on August 22, 1963, and approved at a meeting of the State Board of Health at Raleigh, North Carolina, on January 9, 1964, and subsequently amended at meeting of North Carolina State Board of Health at Canton, North Carolina, on September 19, 1968.

Certified as a true copy

Jacob Koonan

State Health Director

Supplement to Health Bulletin

SBH-SED
September 24, 1968

RESOLUTION TO BE ADOPTED BY THE BOARD OF COMMISSIONERS DESIGNATING OFFICIAL TO SIGN NECESSARY PAPERS AND TO OTHERWISE REPRESENT BOARD IN CONNECTION WITH MOSQUITO CONTROL

Upon motion of _____ (Name), seconded by _____ (Name), it is hereby ordered that _____ (Name), as agent for _____ (Governmental Unit), is hereby authorized and empowered to sign and execute all papers and documents necessary in connection with the request made to the North Carolina State Board of Health for aid in the control of mosquitoes. He is further authorized and required to carry out all agreements stipulated in the project application submitted by us to the North Carolina State Board of Health and to perform other acts that are proper and necessary in connection with the operation of this project. Acts of said person in behalf of said _____ (Governmental Unit) are in all respects validated, approved and confirmed.

The undersigned _____, clerk of the _____ (Governing Body) of _____ (Governmental Unit) hereby certifies that the foregoing is a true copy of the resolution of the _____ (Governing Body) at a meeting held on the _____ day of _____, 19

_____
Clerk

SBH Form 1239 (7/57)
Sanitary Engineering

STATE OF NORTH CAROLINA

JAMES E. HOLSHOUSER, JR
GOVERNOR

DAVID T. FLAHERTY
SECRETARY

DEPARTMENT OF HUMAN RESOURCES

Division of Health Services

JACOB KOOMEN, M.D., M.P.H
DIRECTOR

P. O. Box 2091 Raleigh 27602

Based on local anticipated expenditures shown on the Application for State Aid in Mosquito Control during the current fiscal year, we have made the following allocation for the adulticiding program:

Total State Allocation	$_____
Initial Payment (Check Attached)	$_____
BALANCE DUE	$_____

Applicants are reminded that the Division of Health Services regulations require that the recipients of State funds submit monthly reports showing the work performed, expenditures made, facilities utilized, and materials expended. In the case of those projects that have a balance due, subsequent payments from that amount will be governed by expenditures reported to this office on monthly reports.

The auditing procedures for mosquito control projects have been changed by the Office of the State Auditor. It has been determined that unmatched State funds will have to be returned to the State at the end of each fiscal year rather than allowed to become part of the next fiscal year's allocation.

Very truly yours,

Sidney H. Usry

Sidney H. Usry, Head
Solid Waste & Vector Control Branch
Sanitary Engineering Section

NORTH CAROLINA STATE BOARD OF HEALTH

APPLICATION FOR STATE AID IN MOSQUITO CONTROL

APPLICANT: _____ DATE: _____
(Board of Health, City Council, etc.)

ADDRESS: _____

Application is hereby made to the North Carolina State Board of Health for aid in mosquito control for the fiscal year ending June 30, 19___. The applicant has appropriated the funds shown below for mosquito control during the fiscal year and has in its possession, or otherwise available, the other assets and facilities listed.

CASH APPROPRIATION: (a) Adulticiding ---------- $ _____

(b) Water Management ---------- $ _____

EQUIPMENT RENTAL: ---------- $ _____
(Attach itemized equipment list with rental computed according to attached schedule)

TOTAL LOCAL ASSETS $ _____

As the duly authorized official of the applicant, I have drawn and herewith submit this application for mosquito control aid. I agree that the following provisions of this instrument shall be binding upon the use or expenditure of any funds or other assets allocated:

A. To assume such responsibility for claims for damage resulting from the operation of the project as is necessary to absolve the State or any of its departments or agencies from any liability whatsoever from such claims.

B. To submit such plans as may be required to the North Carolina State Board of Health, and to perform all work in conformity with the plans that are approved by the appropriate representative of the State Board of Health.

C. To use funds provided by the North Carolina State Board of Health and those shown on the project application as being provided by the applicant exclusively for mosquito control, in accordance with the approved plan and the regulations of the State Board of Health.

D. To perform all mosquito control under the direction of a competent supervisor whose qualifications meet the approval of the North Carolina State Board of Health.

E. To submit reports at the end of each month showing work performed during the month, expenditures made, facilities utilized, and materials expended.

F. To submit a certified financial statement to the North Carolina State Board of Health no later than ten days after the last day of December and June of each year. Such statement must include an itemized account of expenditures during the preceding six months, of both local and State funds, as well as an itemized account of other assets and facilities that have been utilized to carry out the mosquito control project.

G. To return to the North Carolina State Board of Health, at the end of December and June of each year, all State funds that were not matched by the expenditure of local funds, or the monetary value of other facilities utilized for mosquito control purposes during the preceding six-months' period.

_____
(Board of Health, City Council)

BY: _____
(Signature of Authorized Official)

_____
(Official Title)

APPROVED: _____
(Health Director's Approval is Required if Applicant is Other than Health Department)

DATE: _____

N.C. State Board of Health

LOCATION: ____________________
PROJECT NO. ______

PROJECT ALLOCATION AND SUMMARY OF EXPENDITURES & ALLOWABLE CREDIT AS COMPILED FROM MONTHLY PROJECT REPORTS

PROJECT ALLOCATION

YEAR	TOTAL STATE ALLOCATION	MATCHING DIFFERENCE	NET STATE ALLOCATION	INITIAL PAYMENT	BALANCE DUE	REVISED ALLOCATION	FINAL PAYMENT

SUMMARY OF EXPENDITURES & ALLOWABLE CREDIT AS COMPILED FROM MONTHLY PROJECT REPORTS

MONTH	SALARIES	INSECTICIDE AND SOLVENTS	EQUIPMENT OPERATION & MAINTENANCE	TOTAL EXPENDITURES	EQUIPMENT RENTAL	TOTAL ALLOWABLE CREDIT	MATCHING DIFFERENCE
JULY							
AUGUST							
SEPTEMBER							
OCTOBER							
NOVEMBER							
DECEMBER							
TOTALS							
DEC. AUDIT							
JANUARY							
FEBRUARY							
MARCH							
APRIL							
MAY							
JUNE							
TOTALS							
JUNE AUDIT							
YEAR TOTAL							
AUDIT TOTAL							

REMARKS: ____________________

SBH FORM 1146
Sanitary Engineering

MONTHLY REPORT OF SALT MARSH DRAINAGE FOR MOSQUITO CONTROL

To: N.C. State Board Of Health
Sanitary Engineering Division
Insect & Rodent Control Section

Location: _____
Project No. _____
Month _____

EXCAVATING EQUIPMENT	INITIAL COST	ECONOMIC LIFE	DEPRECIATION
			___ % Initial Cost $ _____
			___ " " " $ _____
			___ " " " $ _____
			___ " " " $ _____

TOTAL DEPRECIATION $ _____

SALARIES, WAGES, ETC.

Name	No. Hours	Rate/Hour	
			$
			$
			$
			$
			$
			$
			$
			$
			$
			$

TOTAL SALARIES, WAGES $ _____

OPERATION & MAINTENANCE:
Repairs, Maintenance, & Supplies _____ $ _____
Fuel Oil, Gasoline, & Lubrication _____ $ _____
Incidental Costs _____ $ _____

TOTAL OPERATION & MAINTENANCE $ _____

TOTAL EXPENDITURES $ _____

WORK ACCOMPLISHED:
Lin. Ft. Dykes Built _____
Lin. Ft. Ditches Cut _____
Lin. Ft. Ditches Cleaned _____
Cu. Yds. Excavated _____
Acres Filled _____

EQUIPMENT OPERATION
Machine Hours _____
Service Truck Hours _____
Other (Specify) _____
_____
_____
_____

UNIT COST
_____ Per Ft.
_____ Per Yd.
_____ Per Hr.

REMARKS: _____

_____
(Signed)

Date _____

MONTHLY REPORT OF MOSQUITO CONTROL

TO: N. C. Department of Human Resources
Division of Health Services
Solid Waste & Vector Control Branch
Sanitary Engineering Section

_____ Project No. _____ Month _____ 19___
(Governmental Unit Reporting)

WORK PERFORMED

SPACE APPLICATION

Insecticide Used

Type _____ Strength (%) _____ Gallons _____
Type _____ Strength (%) _____ Gallons _____
Type _____ Strength (%) _____ Gallons _____

Labor Cost $_____

LARVICIDING

Lin. ft. of ditches and canals _____ Acres of ponds and swamps _____

Insecticide and Solvent Used

Type _____ Strength (%) _____ Gallons _____
Type _____ Strength (%) _____ Gallons _____
Type _____ Strength (%) _____ Gallons _____

Labor Cost $_____

DRAINAGE, FILLING, AND DYKING

Lin. ft. of ditches cut _____ Lin. ft. of ditches cleaned _____
Lin. ft. of dykes built _____ Acres filled _____

Labor Cost $_____

REMARKS: _____

_____

_____

_____

_____

DHS Form 1235 (Rev. 10/70)
Solid Waste & Vector Control Branch

EXPENDITURES

SALARIES ---------- $ _____

INSECTICIDES, SOLVENTS, AND ADDITIVES PURCHASED:

Type _____ Gallons _____ $ _____
Type _____ Gallons _____ $ _____
Type _____ Gallons _____ $ _____
Type _____ Gallons _____ $ _____

Total Expenditures for Insecticides, Solvents, and Additives ----- $ _____

EQUIPMENT OPERATION AND MAINTENANCE EXPENSES:

Grease, Oil, and Gasoline ---------- $ _____
Other Expenditures: (Explain in detail) _____ $ _____
_____ $ _____
_____ $ _____
_____ $ _____
_____ $ _____
_____ $ _____
_____ $ _____

Total Expenditures for Operation and Maintenance ---------- $ _____

TOTAL CASH EXPENDITURES ---------- $ _____

EQUIPMENT RENTAL

Type of Equipment	Hours Operation	Rate Per Hour	Credit
			$
			$
			$
			$
			$
			$
			$

Total Equipment Rental Credit ---------- $ _____

TOTAL EXPENDITURES AND OTHER ALLOWABLE CREDIT ---------- $ _____

REMARKS: _____

_____

_____

Signed _____

Date _____

WATER MANAGEMENT & MOSQUITO CONTROL AUDIT REPORT

TO: Solid Waste & Vector Control Branch
Sanitary Engineering Section
Division of Health Services
N. C. Departmentof Human Resources
P. O. Box 2091
Raleigh, North Carolina 27602

_____ Project No. _____ Month _____ Year _____

DATE	VOUCHER NUMBER	PAYEE	DESCRIPTION	AMOUNT

TOTAL EXPENDITURES AND ALLOWABLE CREDITS $ _____

DHS Form 1855
Solid Waste & Vector Control Branch

1. SALARIES

   A. Miscellaneous Laborers, Ditching, etc. $_____

   B. Truck Operator Salary for Fogging Machine $_____

   TOTAL $_____

2. INSECTICIDES AND SOLVENTS PURCHASED DURING MONTH

   Type and Name _____

3. EQUIPMENT OPERATION AND MAINTENANCE EXPENSES $_____

4. EQUIPMENT RENTAL

   A. Fogging Machine(s) $_____

   B. Truck(s) $_____

   TOTAL $_____

TOTAL EXPENDITURES AND ALLOWABLE CREDIT $_____
(Same as Page 1)

11. FURTHER INFORMATION AND SOURCES OF SUPPLIES

11. FURTHER INFORMATION AND SOURCES OF SUPPLIES

11.1 INFORMATION

Annon. 1967. Pictorial keys to arthropods, reptiles, birds and mammals of public health significance. U.S. Dept. HEW, Communicable Disease Center (Atlanta, Ga.), 192 p.

Annon. 1972. Mosquitoes and their control. Solid Waste and Vector Control Section, Sanitary Engineering Division, N. C. State Board of Health, Bulletin No. 486, 17 p.

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Axtell, R. C. 1973. Tests of chemicals and ULV (ultra low volume) methods for control of coastal biting flies (mosquitoes, sand flies and tabanid flies). Annual Report, Dept. of Entomology, N. C. State Univ., 54 p.

Battle, F. V. and E. C. Turner, Jr. 1971. A systematic review of the Genus Culicoides (Diptera: Ceratopogonidae) of Virginia. The Insects of Virginia: No. 3, Va. Poly. Tech. Inst. Research Div. Bulletin 44, 129 p.

Carpenter, S. J. and W. J. LaCasse. 1955. Mosquitoes of North America. Univ. California Press, 360 p.

DeBord, D. V., G. A. Carlson and R. C. Axtell. 1974. Demand for and cost of salt marsh mosquito abatement. N. C. Sea Grant Program Publication (in preparation).

Dukes, J. C. and R. C. Axtell. 1974. Information and suggestions for use of ULV ground equipment for mosquito and biting fly control. 29 p.

Gerhardt, R. R., J. C. Dukes, J. M. Falter, and R. C. Axtell. 1973. Public opinion on insect pest management in coastal North Carolina. N. C. Agric. Ext. Serv. Misc. Publ. 97, N. C. Sea Grant Publ. UNC-SG-73-03, 81 p.

Hotchkiss, N. 1970. Common marsh plants of the United States and Canada. U. S. Bureau of Sport Fisheries and Wildlife, Resource Publication 93, 99 p.

King, W. V., G. H. Bradley, C. N. Smith and W. C. McDuffie. 1960. A handbook of mosquitoes of the southeastern United States. USDA Agric. Handbook No. 173.

Kuenzler, E. J. and H. L. Marshall. 1973. Effects of mosquito control ditching on estuarine ecosystems. UNC Water Resources Research Institute Report No. 81, 83 p.

LaSalle, R. N. and K. L. Knight. 1973. The effects of ditching on the mosquito populations in some sections of Juncus salt marsh in Carteret County, North Carolina. UNC Water Resources Research Institute Report No. 82, 162 p. (available from: 124 Riddick Bldg., North Carolina State University, Raleigh, N. C. 27607).

LaSalle, R. N. and K. L. Knight. 1974. The effects of some impoundments on mosquito populations in sectioning of Juncus salt marsh in Carteret and Pamlico counties, North Carolina. UNC Water Resources Research Institute, Report No. 92, 85 p.

Pechuman, L. L. 1973. Horse flies and deerflies of Virginia (Diptera: Tabanidae). The Insects of Virginia: No. 6, Va. Poly. Tech. Inst. Research Div. Bulletin 81, 92 p.

Water Resource Research Institute. 1970. Proceedings Workshop on Mosquito Control in North Carolina. UNC Water Resources Research Institute, Report No. 36.

White, C. M. (Chairman). 1957. Report of the North Carolina Salt Marsh Mosquito Study Commission. Raleigh, N. C., 101 p.

11.2 SOURCES OF SUPPLIES

Bel-Art Products, Pequannock, New Jersey 07440
Polypropylene pint jars and caps.

Carolina Biological Supply Company, Burlington, N. C. 27215
Insect collecting and preserving supplies and equipment

Commercial Plastic and Supply Corp., P. O. Box 25638, Raleigh, N. C. 27611
Sheets of cellulose acetate (.015 in.)

Concession Supply Company, 3916 Secor Road, Toledo, Ohio 43613
Light traps

Fisher Scientific Company, 3315 Winston Road, N. C.
Glassware, chemicals, microscopes, vials, etc.

Gerard Daniel Company, 5 Plain Avenue, New Rochelle, N. Y. 10801
Fine mesh screening

Gulva Associates, P. O. Box 249, Belle Chasse, Louisiana 70037
Drop size determination slides and counting service

Scientific Products, 3713 North Davidson Street, Charlotte, N. C. 28205
Glassware, chemicals, microscopes, vials, etc.

Tanglefoot Company, Grand Rapids, Michigan
"Bird Tanglefoot"

Tri-State Plastic Molding Company, Box 337, Henderson, Kentucky
Clear plastic containers

Wards Natural Science Establishment, P. O. Box 1712, Rochester, N. Y. 14603
Insect collecting and preserving supplies and equipment

University of North Carolina Sea Grant Publications

UNC-SG-72-01. Lyman, J. and W. Rickards. University of North Carolina Sea Grant Program, Annual Report 1 July 1070 - 30 June 1971.

UNC-SG-72-02. Wurfel, S. W., ed. Attitudes regarding a law of the sea convention to establish an international seabed regime.

UNC-SG-72-03. Upchurch, J. B. Sedimentary phosphoris in the Pamlico estuary of North Carolina.

UNC-SG-72-04. Chleborowicz, A. G. Direct oil fired heat exchanger for a scallop shucking machine.

UNC-SG-72-05. Angle, N. B. Insulation of ice bunkers and fish holds in older fishing vessels.

UNC-SG-72-06. Edzwald, J. K. Coagulation in estuaries.

UNC-SG-72-07. University of North Carolina. Proposal for institutional Sea Grant support.

UNC-SG-72-08. Schwartz, F. J. and J. Tuler. Marine fishes common to North Carolina.

UNC-SG-72-09. Porter, H. J. and J. Tyler. Sea shells common to North Carolina.

UNC-SG-72-10. Woodhouse, W. W., E. D. Seneca, and S. W. Broome. Marsh building with dredge spoil in North Carolina.

UNC-SG-72-11. Copeland, B. J. Nutrients in Neuse River and Albermarle Sound estuaries, North Carolina: survey (in preparation).

UNC-SG-72-12. Whitehurst, J. H. The menhaden fishing industry of North Carolina.

UNC-SG-72-13. Schoenbaum, T. J. Public rights and coastal zone management.

UNC-SG-72-14. Tung, C. C. and N. E. Huang. Some statistical properties of wave-current force on objects.

UNC-SG-72-15. Tung, C. C. and N. C. Huang. Wave-current force spectra.

UNC-SG-73-01. Wurfel, S. W. The surge of sea law.

UNC-SG-73-02. Williams, A. B., G. S. Posner, W. J. Woods, and E. E. Deubler, Jr. A hydrographic atlas of larger North Carolina sounds.

UNC-SG-73-03. Gerhardt, R. R., J. C. Dukes, J. M. Falter, and R. C. Axtell. Public opinion on insect pest management in coastal North Carolina.

UNC-SG-73-04. Rickards, W. L. A bibliography of artificial reefs and other manmade fish attractants.

UNC-SG-73-05. Tyler, J., M. McKenzie, and D. King. To catch a million fish.

UNC-SG-73-06. Graetz, K. Seacoast plants of the Carolinas for conservation and beautification.

UNC-SG-73-07. Campbell, P. Studies of brackish water phytoplankton.

UNC-SG-73-08. Samet, J. H. and R. L. Fuerst. The Latin American approach to the law of the sea.

UNC-SG-73-09. Rhyne, C. F. Field and ecological studies of the systematics and ecology of Ulva curvata and Ulva rotundata.

UNC-SG-73-10. Kuenzler, E. J., A. F. Chestnut and C. M. Weiss. The structure and functioning of brackish water ecosystems receiving treated sewage effluent III, 1971-72.

UNC-SG-73-11. Dahle, E. The continental shelf lands of the United States: mineral resources and the laws affecting their development, exploitation and investment potential.

UNC-SG-73-12. Schwartz, F. J. and A. F. Chestnut. Hydrographic atlas of North Carolina estuarine and sound waters, 1972.

UNC-SG-73-13. Lyman, J. and W. Rickards. University of North Carolina Sea Grant Program, Annual Report, 1 July 1971 - 31 December, 1972.

UNC-SG-73-14. Broome, S. W., W. W. Woodhouse, and E. D. Seneca. An investigation of propogation and the mineral nutrition of Spartina alterniflora.

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UNC-SG-73-15. Amein, M. Computation of flow through Masonboro Inlet, North Carolina.
UNC-SG-73-16. Knowles, C. E. CTD Sensors, specific conductance and the determination of Salinity.
UNC-SG-73-17. Tung, C. C. and N. E. Huang. Peak distribution of random wave-current force.
UNC-SG-73-18. Thomas, F. B., T. M. Miller and N. B. Webb. Development, function and operation of the coastal seafood laboratory.

UNC-SG-74-01. Wurfel, S. W. International fishery law (in preparation)
UNC-SG-74-02. Wurfel, S. W. Emerging ocean oil and mining law.
UNC-SG-74-03. Wurfel, S. W. Current aspects of sea law.
UNC-SG-74-04. Riggs, S. R. and M. P. O'Connor. Coastal sediment process associated with a major transgressive system (in preparation)

Available from: Sea Grant Program, 1235 Burlington Laboratories, North Carolina State University, Raleigh, North CArolina 27607